Accurate Delayed Matching-to-Sample Responding without Rehearsal: An Unintentional Demonstration with Children

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Abstract Research on joint control has focused on mediational responses, in which simultaneous stimulus control from two sources leads to the emission of a single response, such as choosing a comparison stimulus in delayed matching-to-sample. Most recent studies of joint control examined the role of verbal mediators (i.e., rehearsal) in evoking accurate performance. They suggest that mediation is a necessity for accurate delayed matching-to-sample responding. We designed an experiment to establish covert rehearsal responses in young children. Before participants were taught such responses; however, we observed that they responded accurately at delays of 15 and 30 s without overt rehearsal. These findings suggest that in some cases, rehearsal is not necessary for accurate responding in such tasks.

Keywords Covert behavior · Joint control · Multiple control · Response strength · Stimulus control

Delayed matching-to-sample (DMTS) tasks consist of a sequence of three components: (1) the presentation of a sample stimulus, (2) a delay, during which neither sample nor comparison stimuli are visible, and (3) presentation of the comparison stimuli. The task is to select the comparison stimulus that matches the sample stimulus. Several studies have shown that humans often engage in “mediating” responses, which appear to facilitate performance in such tasks (e.g., Causin, Albert, Carbone, & Sweeney-Kerwin,

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2013; Lowenkron, 1984; Sidener & Michael, 2006). An example is tacting the sample stimulus when it is presented and then echoing the name during the delay until the comparison stimuli are presented. Upon presentation of the comparison stimuli, correspondence between the mediating response and the tact evoked by one of the comparison stimuli controls the selection response. This analysis is the cornerstone of joint control theory, as developed by Lowenkron (1984, 1988, 1991, 1998, & 2006).

Many joint control studies have arranged conditions so overt mediating responses occurred, using children as participants (e.g., Lowenkron, 1984). In contrast, Gutierrez (2006) used typical adults as participants. After training with a mediation response, Gutierrez's participants were asked to sing a children's song instead of emitting the mediating response (echoing a sequence of words). This manipulation disrupted performance, and Gutierrez concluded that singing "blocked" the mediation. However, more evidence may be needed to convincingly demonstrate covert mediation.

As a step in this direction, we initiated an experiment designed to teach preschool children to tact and select picture cards and then test them on a DMTS task with those cards. Prior joint control research suggested that mediational responding would be necessary to complete this task. Assuming this was true, we intended to teach the children to emit overt echoic mediation responses during the delay and then reduce the magnitude of echoic mediation through shaping until it was putatively occurring covertly. Results indicated, however, that all participants performed well under the DMTS procedure without mediating response training. Therefore, the experiment ended before the shaping procedure was implemented. The following is a brief summary of the procedures and findings.

Method

Participants, Setting, and Materials

Participants were seven typically developing 3–6-year-old children, four boys and three girls. Prior research (Ferraro, Francis, & Perkins, 1971; Sidener & Michael, 2006) indicated that children of this age are unlikely to already possess the mediating repertoire supposedly required to perform DMTS. Sessions were conducted with the experimenter and participant seated at tables located in quiet rooms. A variety of preferred stimuli, unique to each participant, were used as consequences for correct responses during training trials, selected based on an informal free-operant preference assessment.

Materials included sets of picture cards, randomly assigned as training, probe, and generalization sets. Table 1 shows a complete list of the names of the objects depicted on each card. The different sets were used to investigate if generalizable skills were being taught and to help control for practice effects. The original experiment was to train tact and selection responses with the training and probe sets, then train mediation with the training set. DMTS performance would be assessed with the probe set following mediation training. At the end of the experiment, the generalization set would have been used to control for practice with the probe set. Because mediation training was not carried out as originally planned, the distinction between training and probe sets was irrelevant.

Table 1 Picture card names

Common objects				Uncommon objects		
Set 1	Set 2	Set 3	Set 4	Set 1 Animals	Set 2 Leaves	Set 3 Gems
Pants	Football	Clock	Table	Serval	Oak	Pearl
Rocket	Book	Toilet	Couch	Warthog	Maple	Ruby
Scissors	Shoe	Teapot	Trashcan	Antelope	Fern	Sapphire
Tiger	School Bus	Dolphin	Television	Armadillo	Sassafras	Diamond
Orange	Monkey	Screwdriver	Sock	Wombat	Pine	Emerald
Purse	Pencil	Broom	Guitar	Iguana	Poison Ivy	Onyx
Crackers	Balloon	Cereal	Shovel	Platypus	Palm	Turquoise
Mailbox	Trophy	Hammer	Dog	Sloth	Willow	Opal
Banana	Toothbrush	Lawnmower	Cat			
Giraffe	House	Fork	Cloud			
Radio	Bike	Tree	Sun			
Ice cream	Heart	Umbrella	Ribbon			
Earth	Coffee	Cookie	Glasses			
Basketball	Boat	Lamp	Snowman			
Spoon	Pizza	Brush	Phone			
Vacuum	Keyboard	Puzzle	Strawberry			
Key	Stapler	Sweater	Broccoli			
Baseball	Flowers	Chair	Airplane			
Toaster	Feather	Elephant	Kite			
Flag	Apple	Soccer Ball	Mouse			

All pictures were printed in color and laminated. Source pictures are available from the first author. Sets were randomly assigned as training, probe, and generalization sets for each participant

Measurement

The lead author or a research assistant collected data in person or via a video recording. A correct response was defined as the participant saying the name of a picture in the tact training phases, picking up the target picture in the manded selection and probe phases and repeating the target word at least once per second for 10 s in the echoic phase.

Interobserver Agreement and Treatment Integrity

A trained research assistant independently scored 37 % of sessions for interobserver agreement (IOA) and 33 % of sessions for treatment integrity. A minimum of 30 % of sessions were recorded for each phase and each participant. Mean IOA ($[\text{agreements} / (\text{agreements} + \text{disagreements})] \times 100$) was 99.8 % (range, 90 % to 100 %). Research assistants collected treatment integrity measures via a task analysis checklist of each procedure; mean integrity was 96.1 % (range, 68.3 % to 100 %).

Procedures

All sessions consisted of one trial for each picture card. During all phases, cards were presented in a random order. All training phases lasted until a participant showed 100 % accuracy on the task across two sessions. The phases of the experiment are described below, and each participant's progression through these phases is described in the “Results” section.

Tact training The experimenter showed the participant a picture and said, “this is a (name of picture); what is it?” and waited up to 5 s for an answer. Tacting was tested by presenting the picture without the verbal prompt. Correct tacts were reinforced by praise and access to preferred stimuli, and errors were corrected by stating the name of the picture and prompting the participant to repeat it.

Manded selection response training Each participant was taught to select a picture from an array of eight when the experimenter said, “find the (name of picture).” Correct responses were followed by the delivery of praise and access to preferred stimuli, and the experimenter corrected errors by picking up the target card, saying, “this is the (name of picture).” Then, he put the picture back in the array, and said, “now, you find the (name of picture).” The location of picture cards in the array was randomized for each trial.

Delayed matching-to-sample probe For each picture card, the experimenter held it up to the participant, said, “what is it,” waited 5 s for the participant to tact the picture, then removed the picture from view and placed it out of sight on a tray with seven other pictures. After 15 s, the experimenter moved the tray in front of the participant and said, “find it.” The experimenter followed both correct and incorrect responses by saying, “OK” and started the next trial. If the participant repeated the name of the picture during the delay (none did), the experimenter was to say, “no talking,” end the trial, and move to the next trial.

Echoic training Echoic training was the first of several planned phases to teach mediating responses. Participants were trained to repeat the name of each picture card for 10 s in the absence of the picture card, in response to the experimenter saying “say (name of picture)” while making a circular motion with their hand (an echoic-gesture prompt; Tu, 2006). If participants did not repeat the name of the picture card, the experimenter modeled the response.

Delayed matching-to-sample with prompted echoes The DMTS task was identical to the probe phase, except that during the delay, the experimenter prompted the participant to repeat the picture card name during the delay, using the echoic-gesture prompt described above. If the participant did not echo during the delay, the experimenter modeled correct performance.

Modified probes When the first three participants (1001, 1002, and 1003) unexpectedly made correct selection responses after 15 s with no overt rehearsal, two additional probe phases were designed. The first was identical to the 15-s delay test, but with a 30-s delay. The second was identical to the 15-s probe, except that during the delay, the

Table 2 Percentage correct in probe phases and training sessions to mastery

Phase	Participant						
	1001	1002	1003	1005	1007	1008	1009
Tact training	8	5	4	3	4	4	2
Selection training	7	2	2	3	2	2	2
First probe phase							
15-s probe, no distractors	5 %	75 %	75 %	100 %	95 %	60 %	95 %
30-s probe, no distractors				80 %	98 %	60 %	100 %
15-s probe, with distractors				45 %	85 %	80 %	70 %
Echoic training	4	1	1	3			
Second probe phase							
15-s probe, no distractors	98 %	95 %	90 %				
30-s probe, no distractors	80 %						
15-s probe, with distractors	65 %			58 %			
DMTS with prompted echoic training				1			
Third probe phase							
15-s probe, with distractors				95 %			
Generalization set, tact training	1		1	4			
Generalization set, selection training	1		1	1			
Generalization set probe phase							
15-s probe, no distractors	100 %		100 %	95 %			
Uncommon objects tact training				4	7	4	12
Uncommon objects selection training				2	2	1	
Uncommon objects probe phase							
15-s probe, no distractors				88 %	88 %	100 %	100 %

All training phases measured in sessions to mastery. Probe phases measured in percentage correct. The italicized value is what would be expected due to chance

experimenter showed the participant six to eight pictures (distractors) different from the target picture. The distractor pictures appeared alongside the target picture as comparison stimuli following the delay.

Results

Table 2 displays the results of the experiment. Every participant but one (1001) demonstrated better than chance performance on a DMTS task with picture cards after being trained to tact and select those cards.

Participants 1001, 1002, and 1003 proceeded through the study nearly simultaneously. Participant 1002 was the first to reach the first probe and scored above what would be expected due to chance. She went through the echoic training phase and another probe phase and performed nearly perfectly. At this point, she was considered an

anomaly, perhaps already covertly rehearsing, and left the study. Participant 1003 was the next to complete the probe phase and performed nearly as well as the previous participant before and after the echoic training phase. He was then trained to tact and select (but not echo) the generalization set. He performed perfectly in a probe with that set and left the study. Participant 1001 scored below chance on the first probe phase. After echoic training, however, his performance immediately jumped to 98 % correct without any overt rehearsal.

With three participants mastering the DMTS task well before what was expected, modified probes were implemented. Participant 1001 was then tested with longer delays and with distractor cards, which resulted in some decrements in performance, but responding was still far above chance levels. When he was tested with the generalization set without echoic training, he scored perfectly. With a new set of participants ready to start the study, the researchers decided all of them would be tested with longer delays and distractor cards if initial probe performance was above chance.

Participant 1005 scored perfectly on her initial probe phase, with decrements in performance during longer or distractor probe phases (both still above chance levels). After echoic training, her performance with the 15-s delay probe with distractor cards improved. After being trained to overtly echo during the delay, she was accurate in 95 % of trials without overtly echoing. Participant 1005 was then trained to tact and select her generalization set of cards and could complete the DMTS task with distractor cards without any further training.

The uncommon object picture card sets were created to determine if familiarity with the stimuli was a possible variable affecting performance. Participant 1005 was trained and tested with uncommon objects cards, with similar results to tests using common objects. The remaining participants (1007, 1008, and 1009) demonstrated that they could perform the DMTS task with 15-s delays, 30-s delays, distractor cards, and with uncommon object picture cards and did not go through any mediation training phases. Participant 1009 took longer than any other participant to learn to tact the uncommon object cards, and was tested on the DMTS task without manded selection training, to possibly determine if the manded selection training was necessary. She scored perfectly (100 %) without the selection training.

Discussion

In a matching-to-sample task with a 15-s delay, only one of seven participants initially scored below what would be expected via chance (12.5 %, i.e., one target picture in an array of eight comparison stimuli). Arranging longer (i.e., 30 s) delays, using distraction cards, and testing with pictures of uncommon objects did not reduce any participant's performance to chance levels. The relative ease with which participants correctly selected pictures after a delay prevented us from fully implementing the manipulation of interest: training an overt mediating response, then using shaping to reduce its intensity to a covert level. Only one participant (1001) showed any responding that approximated chance levels. Our findings prevented us from examining our proposed experimental question, but did provide evidence that under some conditions children do well in a DMTS task without emitting obvious mediating responses.

We assumed that our participants would have to be taught to emit mediating responses in order to perform the DMTS task, as was shown with the adults in Gutierrez's (2006) study; however, this did not turn out to be the case. Of course, Gutierrez used a rather complex sequencing task, and we used a simple DMTS procedure, which may have contributed to the difference in findings. The current investigation also involved identity matching, rather than symbolic matching, which may explain the discrepant results.

It is possible that the participants in the present study engaged in covert mediational responding without being trained to do so. However, previous findings (e.g., Sidener & Michael, 2006) suggest that children of this age are unlikely to emit mediating responses without being directly taught to do so. Moreover, many of our participants were observed to sometimes talk aloud about other topics during the delay and still select the target card. For example, on one occasion, Participant 1001 told the research assistant about his favorite superhero for almost the full duration of the 15-s delay. When the tray of pictures was presented, he scanned them and selected the correct one. It is unfortunate that we did not anticipate this and collect data on this behavior. Although we cannot rule out covert rehearsal (or lucky coincidence) in such cases, it seems unlikely that covert speech can occur at the same time as overt speech (Palmer, 2009), especially with very young subjects.

The participants in the present study were always required to tact picture cards presented as the sample stimulus, and emitting this tacting response may have directly strengthened the probability of selecting the correct comparison stimulus. Response strength is the probability of the emission of a given response given specific circumstances (Skinner, 1957) and, according to Palmer (2009), is central to the task of predicting and explaining behavior. Of course, response strength, like response probability, is a construct. One cannot legitimately argue that the participants chose the target picture *because* the response was momentarily at strength. Such an analysis is circular, reifies the concepts of response strength and response probability, and explains nothing. However, in many instances, humans appear to be discriminating their own response strength, and Skinner (1957) described verbal responses under the control of response strength as one type of a descriptive autoclitic. As an example, discriminations of response strength may evoke "I'm sure it's aluminum" under some conditions and "I think it's aluminum" under others.

Interestingly, joint control itself can be interpreted as the discrimination of changes in response strength. Palmer (2006) spoke exactly to this point:

A response can be increased in strength without actually being emitted... *Bismarck* was strong – it was “on the tip of her tongue,” as we say – but it was not quite strong enough to be the prepotent response at that moment; competing responses were stronger... However, when the word *Bismarck* was presented as an auditory stimulus, it potentiated a response form that was already strong. The discrepant jump in response strength was a salient event that identified the response as “the answer”... On this account, joint control does not necessarily require the simultaneous presentation of discriminative stimuli. (p. 213, emphasis added with underlines, italics in original).

Consistent with this view, one interpretation of the present findings is that appropriate selection was controlled jointly by the (a) participants discriminating the higher response strength evoked by having seen and tacted a particular card and (b) presentation of that same card in an array of cards. Participants may have discriminated their own higher response strength with respect to picking a picture—the picture “jumped out at them.” Either the discrimination of response strength or the echoic could work in concert with the physical characteristics of a picture to evoke selection of that picture from an array. Another possibility is that participants were able to select the correct card because they engaged in covert imagining of the picture during the delay and based their choice response on correspondence between topographical features of real and imagined stimuli (Skinner, 1957). Experimental evaluation of these two interpretations may prove challenging.

The current results suggest that in some cases, verbal rehearsal (either overt or covert) might not be necessary to respond accurately under DMTS procedures. Future research should focus on determining the behavioral processes that might explain this outcome. It appears likely that those processes involve some form of joint stimulus control. Rehearsal can be viewed as a special case of multiple control, one that often, but not inevitably, accounts for accurate human responding in DMTS tasks. Future research should explore just which kinds of tasks *do* require mediation and what mechanisms are responsible for delayed selection responses when mediation is unlikely.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Human Subjects Institutional Review Board at Western Michigan University and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained for all individual participants included in the study. Participants could leave the study at any time, and assent was obtained at each session with participants, who could leave the table at any time.

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