The Expression of Equivalence Classes Influenced by Distractors During DMTS Test Trials

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When training and testing are conducted with trials presented in a delayed matching to sample (DMTS) format, mediating behaviors may occur during the delay that separates sample offset and comparison onset. In some cases, the mediating behavior can interfere with or enhance the maintenance of correct responding. The present experiment studied how mediating behavior could have influenced responding, according to equivalence classes by manipulation of a distractor task during the delay interval in DMTS test trials for derived relations. After training the baseline relations for equivalence classes, the emergent relations tests were presented with 6-s delays. In Condition A, participants had to solve addition and subtraction tasks during the delay intervals in the emergent relations test trials. In Condition B, no mediating task was presented in the delay interval. These conditions were presented in an ABA or a BAB sequence for different individuals, thereby providing a within-subject assessment of the effects of the distractor task. Regardless of sequence, responding according to equivalence occurred when distractors were not included in the delay interval, and responding according to equivalence was suppressed when distractors were included in the delay interval. The inclusion of a distractor task did not eliminate an already formed class; rather it disrupted responding controlled by class. It also did not interfere with the formation of the equivalence classes. Processes responsible for this outcome were discussed.

Key words: delayed matching to sample, distractors, mediating behavior, stimulus equivalence

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Not very surprisingly the world is full of distractions. Thus, in the present experiment we asked how can it be studied experimentally? A long tradition within behavior analysis in studying complex human behavior has been to employ conditional discrimination procedures (e.g., Arntzen, 2012; Fields, Arntzen, Nartey, & Eilifsen, 2012; Sidman, 1994). In the use of such procedures the role of mediating behavior has been discussed and mediating behavior has been shown to have a variety of influences. Sometimes it enhances the acquisition of conditional discriminations and equivalence class formation, and especially so if the conditional discrimination procedures are arranged in a delayed matching-to-sample (DMTS) format. Although not explicitly trained, the mediating behavior can be interfered with by some distractor task during the delay interval. The present experiment explores those effects on a within-subject basis in the context of the formation and maintenance of equivalence classes.

Conditional discrimination procedures have been the most common procedures to train prerequisites for and the

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testing of equivalence class formation. *Stimulus equivalence* is defined as responding in accordance with the properties of reflexivity, symmetry, and transitivity (e.g., Sidman & Tailby, 1982). Three potential 3-member classes could be trained as A→B and B→C relations arranged as a conditional discrimination procedure or in a matching-to-sample format. For the first relation AB, the A stimuli are the samples (A1, A2, and A3) and the B stimuli are the comparisons (B1, B2, and B3). If A1 is presented, the correct comparison is B1, not B2 or B3. If A2 is presented, the correct comparison is B2, not B1 or B3. If A3 is presented, B3 is correct, not B1 or B2. For the next relation, BC, the B stimuli (B1, B2, and B3) are the sample and the C stimuli (C1, C2, and C3) are the comparisons. If B1 is presented, the correct comparison is C1, not C2 or C3. If B2 is presented, the correct comparison is C2, not C1 or C3. If B3 is presented, the correct comparison is C3, not C1 or C2. Responding in accordance with reflexivity involves responding to the stimuli itself, that is, for example, a participant in the presence of one of the A stimuli selects the same A (when the A stimuli serve both as samples and comparisons). Responding in accordance with symmetry means that when B1 is presented as the sample, the participant selects A1 and not A2 or A3; likewise for B2A2, B3A3, C1B1, C2B2, and C3B3 trials. Responding in accordance with transitivity means that when A1 is presented, the participant selects C1, and not C2 or C3; likewise for A2C2 and A3C3 trials. A global equivalence test presents the C stimuli as samples and the A stimuli as comparisons. The participant is responding in accordance with equivalence if he or she selects A1 and not A2 or A3 in the presence of C; likewise for C2A2 and C3A3 trials.

The above-mentioned conditional discriminations have usually been assessed on trials administered in a simultaneous matching format; on these trials, the sample and comparison stimuli were presented at the same time. When the conditional discrimination procedures are arranged as simultaneous matching, a sample stimulus is presented on the screen and a response to the sample stimulus is followed by the presentation of the comparison stimuli. Both sample and comparison stimuli are presented on the screen until a response to one comparison stimulus is made.

In contrast, however, a fewer studies have administered trials in a DMTS format (e.g., Arntzen, 2006; Barnes, Hegarty, & Smeets, 1997; Fields et al., 1997; Healy, Barnes-Holmes, & Smeets, 2000; Lane, Innis, Clow, & Critchfield, 1998; Saunders, Chaney, & Marquis, 2005). In DMTS, the response to the sample is followed by an immediate offset of the sample and an *n*-s onset of the comparison. The *n* can be 0 s and upwards (e.g., White, 2013). In such arrangements, it is possible to study variables that influence short-term memory or remembering (Arntzen, 2006; Palmer, 1991).

The delay between the offset of the sample and the onset of the comparison; for example delays typically ranged from 0 to 20 s in studies that involved pigeons (Wixted, 1989). With pigeons, the main finding with DMTS procedures is that correct responding in matching tasks decreases with increases in the delay (Sargisson & White, 2001; White, 1985).

For human participants, however, the findings are mixed. In some studies, the acquisition of arbitrary conditional discriminations under delays ranged from 0 to 15 s, and found that acquisition was an inverse function of the duration of the delay (Torgrud & Holborn, 1989). In contrast, Baron and Menich (1985) conducted a similar experiment and did not find a reduction in accuracy as a function of increasing delays.

Four more recent studies (Arntzen, 2006; Arntzen, Galaen, & Halvorsen, 2007; Lian & Arntzen, 2013; Vaidya & Smith, 2006) studied the effects of delay on the formation of equivalence classes and symmetry, two phenomena both of which are more complex than the learning of simple conditional discriminations. These studies showed high rates of responding in accordance with stimulus equivalence even in the context of long delay intervals.

Sidman, Stoddard, Mohr, and Leicester (1971) opined that the solution of conditional discrimination in DMTS formats, requires the occurrence of some behavior that carries forward information about the sample stimulus if the correct comparison is to be selected. This surmise is supported by the results of a classical experiment with DMTS conducted by Blough (1959). Using a DMTS trial format, two of four pigeons responded with low accuracy. The other two, however, maintained high levels of accuracy with increasing delay. Unlike the first two, the latter pigeons maintained accurate matching performance during intervals of long delays by emitting sample-specific, stereotypical responses. The mediating behavior, however, was emergent and was not required by the experimental control. It is likely that it was initially irrelevant behavior that was adventitiously reinforced and then maintained. Cleaveland (1998) found similar results where birds were trained to make distinctive responses to four stimuli that were later used as sample stimuli. Likewise, some earlier studies with humans have shown similar outcomes where meditating behavior was required in DMTS (Parsons, Taylor, & Joyce, 1981; Torgrud & Holborn, 1989).

It follows from this analysis that a task that would disrupt the above mentioned mediating behavior should also interfere with the formation and/or maintenance of conditional discriminations and of equivalence classes. Such tasks will be referred to as distractors. For example, studies with monkeys have shown that correct performance decreased with presentation of distractors in the delay (Artchakov et al., 2009). In a study by DeFulio (2002), five adult human participants were trained in three conditional discriminations; visual-visual discriminations, or auditory-visual discriminations, respectively. The results showed that, for most participants, the accuracy was high even with longer delays (even up to 32 and 64 s). Furthermore, distractors were introduced in the delay between the offset of the sample and the onset of the comparisons: (1) generalized identity matching distraction condition, (2) sample distraction condition, (3) comparison distraction condition, and (4) reading distraction condition. The main finding was that for all participants, accuracy was reduced for at least one condition with distractors; the reading condition reduced the accuracy the most.

Similar findings were obtained with equivalence class formation. In Experiment 4 of Arntzen (2006), participants were exposed to three different conditions, that is, simultaneous, 0-s delay, and 3-s delay. With the 3-s delay, distractors were presented during the delay. The distractors presented in the delays were simple math tasks that involved addition or subtraction tasks of numbers from 1 to 10. Six of six participants responded in accordance with stimulus equivalence in the simultaneous and 0-s-delay conditions, while none of the six participants responded in accordance with stimulus equivalence in the 3-s-delay condition with distractor tasks. One interpretation of the data is that distractors could have reduced the possibility of producing any mediating behavior and, hence, hindered responding in accordance with stimulus equivalence when the test was arranged in a DMTS. The findings need to be replicated and especially in a within-subject design which introduces and removes distractors in test conditions.

The present study is a systematic replication of Experiment 4 in Arntzen (2006). In the present experiment, we determined whether responding in accordance with stimulus equivalence, in which all training and testing is conducted using trials presented in a DMTS format, was hindered by a required distractor task in the delay between sample and comparisons under test conditions. We presented conditions with and without distractors during testing in a DMTS procedure. The effects of distracting stimuli on the formation of equivalence and maintenance of classes were studied by running a series of conditions, with and without distractors, in an ABA and a BAB format. The prediction is that accuracy will be more disrupted in conditions with distractors.

Method

Participants

Twelve participants were recruited from the university college and through personal contacts. The participants were seven women and five men ranging in age from 19 to 42 years, with an average age of 27.4 years. None of the participants had any knowledge about stimulus equivalence or had participated in such experiments previously. Upon arriving at the lab, the participants were given written information about the experiment, which included some general information about the experiment and the experimental situation. They were also told that they could withdraw from the experiment at any time. The participants were debriefed after the experimental session, and their results were explained to them. Finally, they could sign up on a list in which they had the chance to win a lottery for a voucher for 500 Norwegian kroner to use in the cantina at the university college.

Apparatus and Setting

The experimental setting was the laboratory at departement at the university college. The lab cubicle we used was a rectangular room of 12 m^2 with a window covered by curtains (to reduce possible interruption from the outside). The participants were seated at a desk in front of the window. The experiment was run on an HP 8730w laptop with a 17- inch screen and an Intel Core 2 Duo T9800/2.93 GHz processor. To the left of the screen was a second screen, of 19 inches. In addition, the image from the second screen was shown on a third screen on a desk in an adjacent room, so that we could ensure that the participant responded. The experiment used an MTS software made by Psych Fusion Ltd. in collaboration with the first author. Another program, created by the second author, presented the math tasks that were running on the second screen.

Stimulus Sets

Three different sets of abstract visual stimuli were used (see Figure 1). The stimuli in each class were arbitrarily related because there were no physical similarities between the stimuli in the classes. The stimuli were Arabic, Cyrillic, Chinese, or Hebraic letters. We modified some of the stimuli, that is, added or deleted lines, or rotated the stimuli to make them more abstract.

The stimuli were presented on the monitor in rectangular areas (10.5 × 3.8 cm) that were sensitive for the participants' mouse-clicking. The sample stimulus was presented in the middle of the screen; three comparison stimuli were presented randomly in the corners of the screen.

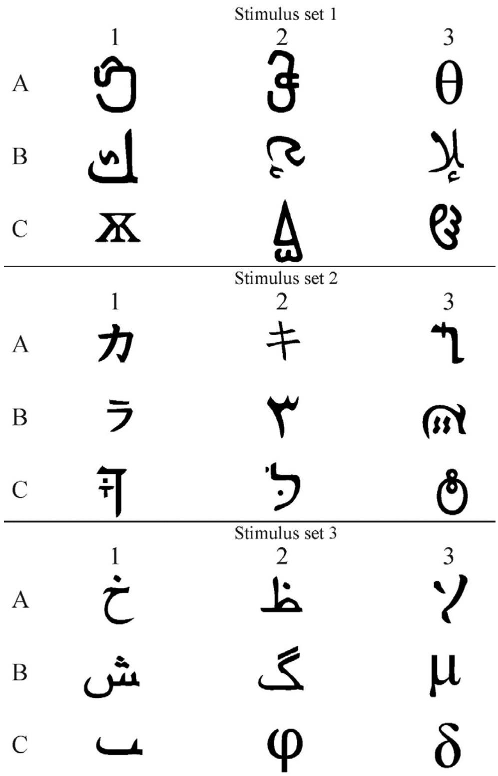

Figure 1. The three different stimulus sets and the abstract stimuli used.

Design

We employed ABA- and BAB-designs—A conditions had no distractors while B conditions had distractors as multiplication and addition tasks (see below for details) during testing. The two testing orders enabled the experiment to determine whether there were history effects that interacted with the distractor requirements. Six of the 12 participants went through the different conditions of the experiment in an ABA design. The first condition was without distractors (A), followed by a condition with distractors (math tasks) during the test (B) and, finally, a condition without math tasks (A). The last 6 participants were exposed to the conditions in a reversed order, BAB.

All 12 participants were first presented Stimulus Set 1 independent of the condition they started with. Stimulus Set 2 was always presented in the second condition. Finally, they were presented with Stimulus Set 3 in the third condition (see Figure 1).

Procedure

For each participant, the experimental sessions were run in *one* day and lasted approximately 3 hrs. The participants had to read the written information and were seated in front of the computer. The experimenter informed the participants that they should turn toward the other screen when the first screen turned white to do the math tasks and say the task and results aloud. The participants were told that they should continue with tasks on the main screen after they had finished the math tasks. They were also informed that the experimenter was going to be in the room during parts of the experimental session to remind the participants to do the math tasks (if they did not start working on them). Finally, the participants were instructed to read the following instructions presented in Norwegian on the screen:

A stimulus will appear in the middle of the screen. Click on this by using the computer mouse. Three other stimuli will then appear. Choose one of these by using the computer mouse. If you choose the stimulus we have defined as correct, words like *very good*, *excellent*, and so on will appear on the screen. If you press a wrong stimulus, the word *wrong* will appear on the screen. At the bottom of the screen, the number of correct responses you have made will be counted. During some stages of the experiment, the computer will not tell you if your choices are correct or wrong. Furthermore, the tasks will be presented on the screen on your left-hand side. Please read the tasks and say the answers aloud. Then, write down the answer on the number pad and touch the Enter key. Based on what you have learned, you should be able to do all the tasks correctly. Please do your best to get everything right. Good luck!

Each trial started with the presentation of a sample stimulus. A click on the sample stimulus was followed by the presentation of three comparison stimuli after a 6-s delay. The comparisons appeared in three of four positions randomly. During the delay the screen was white. If the participant responded correctly, such words as *super, very good, awesome*, and so forth, were presented on the screen. If the participant responded incorrectly, the word *wrong* appeared on the screen. The text stimuli appeared on the screen for 500 ms and were followed by a 500-ms intertrial interval. After each trial, the mouse cursor was reset to a fixed position above the sample stimulus.

The order of training is shown in Table 1. The distractors were not included in the establishment of the baseline relations. Because we wanted to analyze how distractors could influence equivalence class formation, a many-to-one (MTO; training AC and BC relations) training structure arranged trials to be presented on a serialized basis, which has shown to be a very effective procedure to produce such classes (e.g., Arntzen, 2012). Thus, first we trained AC trials and then we trained BC trials. Training in a mixed condition with AC and BC trials followed this. In the first block, the trial types were **A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, and **A3**C1C2<u>C3</u>

(the sample is the first letter and number in each string followed by the three comparisons; the sample is in bold and the correct comparison is in each string is underlined). Each trial type was presented three times. Participants needed to have all trials correct before moving to the next block. In the next block, BC relations were trained. The trial types were **B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, and **B3**C1C2<u>C3</u>. Each trial type was presented three times, and all trials needed to be correct for the participant to move to the next phase. In the next condition, all trial types were presented in mixed order. Hence, the trial types were as follows: **A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>, **B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, and **A3**C1C2<u>C3</u>. Each trial type was presented three times, and the participants needed to have all trials correct to move to the next phase. For all the preceding phases, the probability of programmed consequences was 100%.

Table 1
Overview of the Procedure

Condition	Trial types	Probability for a programmed consequence (percentage)	Criterion
Serialized training	**A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>	100	9 of 9 correct
Serialized training	**B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, **B3**C1C2<u>C3</u>	100	9 of 9 correct
Mixed training	**A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>, **B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, **B3**C1C2<u>C3</u>	100	18 of 18 correct
Mixed training	**A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>, **B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, **B3**C1C2<u>C3</u>	75	18 of 18 correct
Mixed training	**A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>, **B1**C1C2C3, **B2**C1C2C3, **B3**C1C2C3	50	18 of 18 correct
Mixed training	**A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>, **B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, **B3**C1C2<u>C3</u>	25	18 of 18 correct
Mixed training	**A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>, **B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, **B3**C1C2<u>C3</u>	0	18 of 18 correct
Mixed testing: DT, SYM, and EQ	**A1**<u>C1</u>C2C3, **A2**C1<u>C2</u>C3, **A3**C1C2<u>C3</u>, **B1**<u>C1</u>C2C3, **B2**C1<u>C2</u>C3, **B1**C1C2<u>C3</u> (DT) **C1**<u>A1</u>A2A3, **C2**A1<u>A2</u>A3, **C3**A1A2<u>A3</u>, **C1**<u>B1</u>B2B3, **C2**B1<u>B2</u>B3, **C3**B1B2<u>B3</u> (SYM) **A1**<u>B1</u>B2B3, **A2**B1<u>B2</u>B3, **A3**B1B2<u>B3</u>, **B1**<u>A1</u>A2A3, **B2**A1<u>A2</u>A3, **B3**A1A2<u>A3</u> (EQ)	0	

Note. The table shows the different conditions and trial types, in addition to the probability for programmed consequence and the mastery criterion for each condition. In the test block, 54 trials (18 DT trials, 18 SYM trials, and 18 EQ trials) were presented intermixed. DT = directly trained; SYM = symmetry; EQ = equivalence.

In the next phase, the probability of programmed consequences was thinned to 75%, 50%, 25%, and, finally, 0%. The mastery criterion for all mixed phases was 100% correct responding in blocks of 18 trials, with 3 trials of each trial type. The last training phase was followed by a test phase with 54 trials.

The test block contained the directly trained trials: **A1**C1C2C3, **A2**C1C2C3, **A3**C1C2C3, **B1**C1C2C3, B2C1C2C3, along with tests for the emergence of symmetrical relations (**C1**A1A2A3, **C2**A1A2A3, **C3**A1A2A3, **C1**B1B2B3, **C2**B1B2B3, and **C3**B1B2B3) and those for the emergence of the equivalence relations (**A1**B1B2B3, **A2**B1B2B3, **A3**B1B2B3, **B1**A1A2A3, **B2**A1A2A3, and **B3**A1A2A3). All trials were randomly mixed in one test block.

In all the B conditions, during the administration of the test blocks, the distractors were presented during the delays for each test trial — after the offset of the sample stimulus. All of the math tasks involve the presentation of numbers were between 41 and 50. An example of the tasks is 50–47 = _____. The participants answered by using a numeric keyboard that was placed in front of the secondary screen and by saying the answer out loud. This program automatically generated addition and subtraction tasks. Fifty-four different math tasks were employed for each B condition. One math task was presented in each delay in the B conditions. The presentation of the math tasks was signaled by the screen turning from black to white; subsequently, the addition or subtraction math tasks were presented in the upper right corner. The numbers were printed in 72-point Lucida Console font. The application started with a response to the sample stimulus during the test in the MTS program. Thus, a math task was presented as the sample stimulus disappeared from the main screen and remained on the second screen until an answer was given. If the participant touched one of the comparison stimuli or did not fill in any numbers, the task was terminated. The participant was not informed as to whether his or her response was correct.

Behavior Recorded

Clicking on a stimulus was defined as the target response. The criterion for responding in accordance with stimulus equivalence was 17 of 18 correct responses each for the directly trained (baseline), symmetry, and equivalence trials. The MTS software recorded every sample and comparison response made by the participants and also the time from the presentation of the stimulus to the response. The types of math tasks presented, the length of the interval from the presentation until the participant responded, and the answers were recorded automatically.

Results

Figure 2 shows number of participants who responded in accordance with stimulus equivalence in the ABA and BAB sequence, respectively. For the participants in the ABA sequence, in the first A condition, without distractors, all six participants responded in accordance with stimulus equivalence. In the next condition, with distractors (B), only two of the six participants responded in accordance with stimulus equivalence. Finally, in the last A condition, without distractors, five of the six participants once again responded in accordance with stimulus equivalence.

For the participants in the BAB sequence, in the first B condition with distractors, none of the six participants responded in accordance with stimulus equivalence. In the condition without distractors (A), five of six participants responded in accordance with stimulus equivalence, while two of six responded in accordance with stimulus equivalence in the second B condition with distractors.

Details of responding for each participant in the ABA sequence are shown in upper panel of Table 2 All of the participants answered the math tasks, except P3078 who did not answered one math task, and the

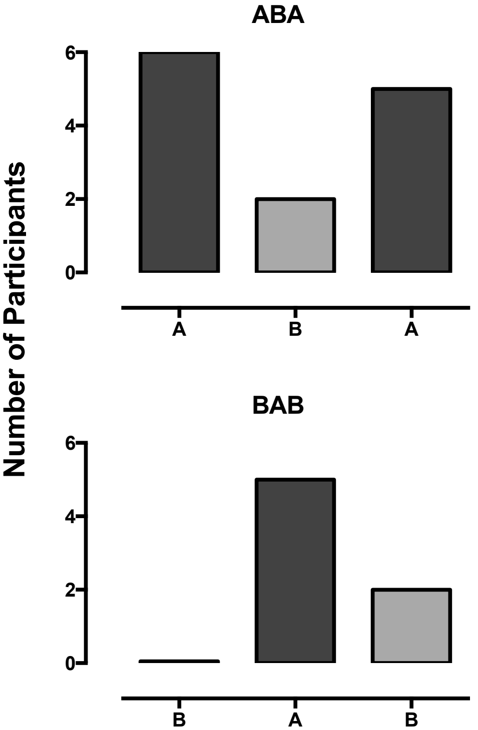

Figure 2. The upper-panel showing the number of particpants responding in accordance to stimulus equivalence in the ABA sequence, while the lower-panel showing the number of participants responding in accordance with stimulus equivalence in the BAB sequence.

participants had overall between 80% and 98% correct answers. The median time the participants were engaged in the math task varied between 5.5 s and 13.7 s. P3078 responded in accordance with stimulus equivalence in all three conditions. P3076 responded in accordance with stimulus equivalence in both conditions without distractors. Furthermore, in the condition with distractors he responded correctly on the symmetry and equivalence trials but not on the directly trained trials. For these participants, the distractor task did not interfere with equivalence-based performances or did so on a selective basis.

Participants 3071, 3075, and 3073 responded in accordance with stimulus equivalence on both conditions without distractors. In the condition with the distractors, they responded correctly on directly trained and symmetry trials but not on equivalence trials. For these participants, the distractor task did interfere with equivalence-based performances.

P3072 responded in accordance with stimulus equivalence in the first condition without distractors, and responded correctly on directly trained and symmetry trials in the second condition without distractors. In the condition with distractors, he did not respond in accordance with stimulus equivalence, although he responded correctly on directly trained and symmetry trials.

Details of responding for each participant in the BAB sequence are shown in the lower panel of Table 2. All participants answered the math tasks and responded between 76% and 96% correct. The median time the participants were engaged in the math task varied between 5.9 s and 10.3 s in the first B condition and 5.2 s and 7.4 s in the second B condition. P3135 responded correctly on the directly trained trials but not on the symmetry and equivalence trials, while in the A condition (without distractors) the participant responded in accordance with stimulus equivalence, with 16 correct of 18 baseline trials, and in accordance with symmetry and equivalence trials. P3142 did not respond in accordance with stimulus equivalence but with symmetry in the first B condition (distractors). In condition A (no distractors) and the second B condition (distractors), he responded in accordance with stimulus equivalence. Participants 3141, 3143, and 3139 did not respond in accordance with stimulus equivalence in the first B condition (distractors) but did so in condition A (no distractors); and P3141 responded in accordance with stimulus equivalence in the second B condition while P3143 and P3139 did not. P3138 did not respond in accordance with stimulus equivalence in any of the conditions. However, the participant responded in correctly on 17 of 18 of the equivalence trials.

Table 2
Results on Responding During Training and Testing in the ABA and BAB conditions

ABA

	No distractors (A)						Distractors (B)								No distractors (A)					
P#	TT	DT	SYM	EQ	SE	ECF	TT	DT	SYM	EQ	SE	ECF	%AMT	MMT	TT	DT	SYM	EQ	SE	ECF
3078	117	**18**	**18**	**18**	**54**	**Y**	117	**17**	**18**	**18**	**53**	**Y**	98	5.7	153	**18**	**18**	**18**	**54**	**Y**
3076	252	**18**	**18**	**18**	**54**	**Y**	135	14	**17**	**18**	49	N	80	10.9	144	**18**	**18**	**18**	**54**	**Y**
3071	162	**18**	**18**	**18**	**54**	**Y**	126	**17**	**18**	15	50	N	83	8.6	126	**18**	**18**	**18**	**54**	**Y**
3075	225	**18**	**18**	**18**	**54**	**Y**	234	**18**	**18**	15	51	N	94	13.7	126	**18**	**18**	**18**	**54**	**Y**
3073	207	**18**	**18**	**18**	**54**	**Y**	171	**18**	**17**	13	48	N	93	7.3	162	**18**	**18**	**18**	**54**	**Y**
3072	180	**18**	**18**	**18**	**54**	**Y**	198	15	16	14	45	N	96	7.6	171	**17**	**18**	15	50	N

BAB

	Distractors (B)								No distractors (A)						Distractors (B)							
P#	TT	DT	SYM	EQ	SE	ECF	%AMT	MMT	TT	DT	SYM	EQ	SE	ECF	TT	DT	SYM	EQ	SE	ECF	%AMT	MMT
3135	189	**18**	15	14	47	N	93	5.9	171	**18**	**18**	**18**	**54**	**Y**	144	16	**17**	**17**	50	N	89	6.2
3142	207	16	**18**	14	48	N	76	7.6	144	**18**	**18**	**18**	**54**	**Y**	117	**18**	**18**	**18**	**54**	**Y**	80	7.2
3141	234	16	15	16	47	N	89	9.8	153	**17**	**18**	**18**	**53**	**Y**	153	**18**	**18**	**18**	**54**	**Y**	83	7.4
3143	189	16	16	12	44	N	94	7.3	162	**18**	**18**	**18**	**54**	**Y**	207	**17**	**17**	15	49	N	96	5.2
3139	423	14	10	14	38	N	96	10.3	180	**18**	**18**	**17**	**53**	**Y**	162	**17**	10	12	39	N	94	6.8
3138	261	15	16	15	46	N	N/A	N/A	504	16	15	**17**	48	N	153	14	14	16	44	N	N/A	N/A

Note. The number of training trials and the correct number of responses for each trial type (directly trained trials, symmetry, and equivalence) are shown for the conditions without distractors (A) and with distractors (B), respectively. The numbers in bold indicate that the number of trials is in accordance with the experimenter defined definitions. The number of trials presented for each trial type was 18 and total number of test trials was 54. P# = Participant number, TT= Training Trials; DT = Directly Trained, SYM = Symmetry probes; EQ = Equivalence probes; SE = total correct in the MIXED test; ECF = Equivalence Class Formation; Y =Yes; N = No; %AMT = Percent Accuracy of Math Tasks; MMT = Median seconds on Math Tasks.

If one takes into consideration the results from the current experiment, there did not appear to be any systematic differences in responding occasioned by directly trained, symmetry, and equivalence trials. This can be an indication that the math task disturbed all the relations to the same degree in DMTS procedures.

Discussion

The main results from the present experiment showed a very high accuracy without distractors (A-conditions) while the inclusion of distractors (B-conditions) reduced responding that was in accordance with stimulus equivalence. These results with the inclusion of distractors replicated the findings of Experiment 4 in Arntzen (2006). We are assuming that accuracy of responding in accordance with equivalence on trials presented in a DMTS format is attributable to mediating behaviors that "carry" forward the sample stimulus so they are "present" when the comparison stimuli are introduced, and thus occasion class indicative responding. It follows that the distractor task results in a breakdown in the test performances because the latter interferes with the evocation of the class controlling response produced mediating stimuli. In general, one form of stimulus control (those in the distractor task) overshadows another form of stimulus control that are cues which occasion class indicative comparison selection (the response product of the mediating behavior in combination with the comparison stimuli).

For the ABA group, all participants showed the emergence of all derived relations in the first A condition, which documented the formation of equivalence classes. These tests were conducted with no distractors during the delay interval that separated the sample offset and comparison onset.

Immediately thereafter, the test was repeated with distractors during the delay interval and class indicative performances were substantially disrupted. These findings could mean that the classes had been undone. Alternatively, the classes were intact during the B condition but the distractor task exerted predominant control of behavior and overshadowed the class based stimulus control topographies. These interpretations were separated by a consideration of the data obtained in the last condition during which the emergent relations tests did not include the distractor task. Under this condition, class indicative performances immediately reemerged and with no intervening retraining. This result supports the view that the classes remained intact during the test trials that contained the distractors. The distractor task, then, did not compromise the integrity of the classes; rather, it suppressed the expression of class indicative behavior or the control by class based stimulus control topographies. To summarize, two discrimination tasks interacted where one was predominant in one condition (Condition A) and was overshadowed by another when two were present on a concurrent basis (Condition B).

The results obtained with the BAB group were consistent with the analysis presented above. The initial test in the B condition contained the distractor task, and no participants showed the emergence of class indicative performances. These data could indicate that classes had not formed due the presence of the distractor task, or that the classes had formed but class indicative stimulus control topographies were not expressed because of being overshadowed by the control exerted by the distractor task; "attention to math rather than to class membership". The subsequent B condition consisted of tests that did not contain distractor tasks, and almost all of the participants showed the presence of the equivalence classes. These results suggest that the classes had formed after training, were present during the initial test with distractors, but the distractor task just overshadowed class based control of responding. It also suggests that the distractor task did not prevent the formation of the classes after the establishment of the baseline relations.

Re-exposure to the test with the distractors resulted in the maintenance of class control for a few of the participants. This could indicate a relative increase in the strength of the class based stimulus control topographies for some of the participants in the group. Assuming the validity of this analysis, the variables that influence the relative strength of class based and distractor task stimulus control topographies are yet to be determined.

For some participants, classes formed or were maintained classes even when the distractor task was present in the delay intervals. How might this occur? One possibility is that a participants 'multitasked', by working on the distractor task in one or a few very short time packets, and repeated the naming of the sample stimuli in other rapidly alternating time packet, which enabled the solution of the conditional discriminations with a delay. This possibility could be evaluated by studying correlations between problem solution and MTS test performances, and between a moment-to-moment tracking of both task.

Such a decrement in class indicative responding, however, is not always found with adult participants; rather, some have reported no decrement with increases in the DMTS delay interval (Baron, Menich, & Perone, 1983; DeFulio, 2002). The differences in outcomes may be driven by the use of different problem-solving strategies in the delay intervals on various experiments. Thus, it is important to consider that participants can use different problem-solving strategies in DMTS experiments, for example, repeating a made-up name for the sample stimulus until the comparisons are presented and a choice is made. It could be that if a participant uses the same strategy in DMTS, it will have some similarities with the repetitive sample-specific behavior seen in Blough (1959).

One can argue that if such mediating behavior occurs, this could facilitate matching accuracy in DMTS procedures with humans. By presenting distractors in the delay, as in the present experiment, such repetitive mediating behavior might not be possible.

In humans, such mediating behavior could be naming the stimuli; it is important to notice that we are talking about naming as name-giving to the stimuli that is more like tacting and different from the term "naming" (listener behavior, tact, and echoic) as used by Horne and Lowe (1996). We prefer to use the term naming as in giving names to stimuli because that has been a consistent way to use the term in the equivalence literature. It could be argued that for matching accuracy to be improved by mediating behavior the name-giving behavior must be sample specific, and, thus, having different mediating behavior or names for each sample. In MTO with 3 classes, as in the present experiment, there are six different mediating behaviors developing in training, one for each of A1, A2, and A3 and one for each of B1, B2, and B3. In the test probes for equivalence (AB and BA), the mediating behavior cannot predict which comparison to choose and likewise for the symmetry tests (CA and CB) since the C has never been a sample before. Mediating naming behavior, however, can be either homogenous (common) or heterogeneous naming. Stromer and Mackay (1996) argued that naming of stimuli in conditional discrimination experiments facilitates the outcome on equivalence tests. They argued for the importance of homogeneous naming—the name will then be common for both sample and comparison stimuli. This prediction has been supported by other experiments (e.g., Dugdale & Lowe, 1990; Eikeseth & Smith, 1992). As Sidman, Stoddard, Mohr, and Leicester (1971) mentioned, "The input must generate some process that 'carries' the sample after it disappears. Naming is the usual bridge between sample and delayed choice" (p. 134). We support the notion about the importance of studying verbal behavior during delays in DMTS and suggest that further research should focus on talk-aloud procedures (e.g., Lane & Critchfield, 1996). Such types of data would be a nice contrast to the data from the present experiments.

One limitation of the present study is related to the time the participants were involved with the distracting tasks; the median time used with the distractor or math tasks varied from 2 to 5.2 s. It could be argued that more is going on here—that the math tasks were not under direct stimulus control. Furthermore, the results from the BAB sequence showed a decrease in the time used on math tasks from the first to second B condition for five of the six participants. Donahoe and Palmer (1994) argued that a decrease in reaction time may indicate a shift in direct stimulus control. This is probably the case if a high number of the same math tasks are presented. The program that presented the distractors was programmed to auto-generate the math tasks that involved the numbers 1 through 10, which constitute up to 145 combinations over 54 trials. To reduce the probability that the same task will be presented more than once, it is possible to increase the number of combinations. This will make it more difficult for the participant to engage in different forms of behavior before the onset of the comparisons.

In sum, the present study gives an example on how distractors influence responding during delays in DMTS can be studied. The main findings from the present experiment show that when distractors were introduced in the delay between the offset of the sample and the onset of the comparisons, the equivalence yields were reduced for individual participants. Based on the findings from the present experiment further research could focus on a number of areas. First, in research of short-term memory, the sample stimulus should not lose control but does so when the distractor task presented in the delay is unrelated to the sample stimulus (Peterson & Peterson, 1959).

Hence, distractors within the same sensory modality have been shown to disrupt more than distractors from a different sensory modality (Artchakov et al., 2009). Since we have employed tasks within the same modality — visual; it might be interesting to study responding in accordance with stimulus equivalence as a function of distractors within a different modality than the stimuli used to form equivalence classes, and to use tasks for which there is lesser probability that the participants had some experience with them. Second, in the present experiment, baseline relations in the B-conditions (testing with distractors) were for some of the participants less than the experimenter-defined criteria. Thus, an experimental arrangement could be to introduce a condition with distractors only for the direct trained trials or baseline trials before the test blocks. We could study how the introduction of distractors influences responding on these trials. Hence, such an experiment could increase control of the effect of distractors before the test is implemented. Finally, an experiment could be arranged to study if the introduction of distractors decreases the sensitivity of the test contingencies. To test if sensitivity to the test contingencies is reduced due to the introduction of distractors, one could introduce distractors after the participants have been exposed to several symmetry and equivalence trials.

References

Arntzen, E. (2006). Delayed matching to sample and stimulus equivalence: Probability of responding in accord with equivalence as a function of different delays. *The Psychological Record, 56*, 135–167. Retrieved from http://thepsychologicalrecord.siuc.edu/index.html.

Arntzen, E. (2012). Training and testing parameters in formation of stimulus equivalence: Methodological issues. *European Journal of Behavior Analysis, 13*, 123–135. Retrieved from http://www.ejoba.org/.

Arntzen, E., Galaen, T., & Halvorsen, L. R. (2007). Different retention intervals in delayed matching-to-sample: Effects of responding in accord with equivalence. *European Journal of Behavior Analysis, 8*, 177–191. Retrieved from http://www.ejoba.org/.

Artchakov, D., Tikhonravov, D., Ma, Y., Neuvonen, T., Linnankoski, I., & Carlson, S. (2009). Distractors impair and create working memory–related neuronal activity in the prefrontal cortex. *Cerbral Cortex, 19*, 2680–2689. doi: 10.1093/cercor/bhp037

Barnes, D., Hegarty, N., & Smeets, P. M. (1997). Relating equivalence relations to equivalence relations: A relational framing model of complex human functioning. *The Analysis of Verbal Behavior, 14*, 57–83. Retrieved from http://www.abainternational.org/TAVB.asp.

Baron, A., & Menich, S. R. (1985). Age-related effects of temporal contingencies on response speed and memory: An operant analysis. *Journal of Gerontology, 40*, 60–70. Retrieved from http://www.geron.org/Publications/The Journal of Gerontology: Psychological Sciences.

Baron, A., Menich, S. R., & Perone, M. (1983). Reaction-times of younger and older men and temporal contingencies of reinforcement. *Journal of the Experimental Analysis of Behavior, 40*, 275–287. doi: 10.1901/jeab.1983.40-275

Blough, D. S. (1959). Delayed matching in the pigeon. *Journal of the Experimental Analysis of Behavior, 2*, 151–160. doi: 10.1901/jeab.1959.2-151

Cleaveland, J. M. (1998). *Stimulus properties of the response during matching-to-sample tasks in pigeons and budgerigars.* Phd Unpublished doctoral dissertation, Duke University, Durham, NC.

DeFulio, A. L. (2002). *A comparison of auditory and visual stimuli in a delayed matching to sample procedure with adult humans.* Unpublished manuscript, University of North Texas, Denton. Retrieved from http://www.library.unt.edu/theses/open/20023/defulio_anthony/thesis.pdf

Donahoe, J. W., & Palmer, D. C. (1994). *Learning and complex behavior*. Boston, MA: Allyn & Bacon.

Dugdale, N., & Lowe, C. F. (1990). Naming and stimulus equivalence. In D. E. Blackman & H. Lejeune (Eds.), *Behaviour analysis in theory and practice: Contributions and controversies* (pp. 115–138). Hillsdale, NJ: Erlbaum.

Eikeseth, S., & Smith, T. (1992). The development of functional and equivalence classes in high-functioning autistic children: The role of naming. *Journal of the Experimental Analysis of Behavior, 58*, 123–133. doi: 10.1901/jeab.1992.58-123

Fields, L., Arntzen, E., Nartey, R., & Eilifsen, C. (2012). Effects of a meaningful, a discriminative, and a meaningless stimulus on equivalence class formation. *Journal of the Experimental Analysis of Behavior, 97*, 163–181. doi: 10.1901/jeab.2012.97-163

Fields, L., Reeve, K. F., Rosen, D., Varelas, A., Adams, B. J., Belanich, J. et al. (1997). Using the simultaneous protocol to study equivalence class formation: The facilitating effects of nodal number and size of previously established equivalence classes. *Journal of the Experimental Analysis of Behavior, 67*, 367–389. doi: 10.1901/jeab.1997.67-367

Healy, O., Barnes-Holmes, D., & Smeets, P. M. (2000). Derived relational responding as generalized operant behavior *Journal of the Experimental Analysis of Behavior, 74*, 207–227. doi: 10.1901/jeab.2000.74-207

Lane, S. D., & Critchfield, T. S. (1996). Verbal self-reports of emergent relations in a stimulus equivalence procedure. *Journal of the Experimental Analysis of Behavior, 65*, 355–374. doi: 10.1901/jeab.1996.65-355

Lane, S. D., Innis, A., Clow, J. K., & Critchfield, T. S. (1998). Preliminary evidence for cross-modal generalized equivalence classes. *Mexican Journal of Behavior Analysis, 24*, 311–337. Retrieved from http://www.rmac-mx.org/editorial.html.

Lian, T., & Arntzen, E. (2013). Delayed matching-to-sample and linear series training structures. The Psychological Record, 63, 545–561. Retrieved from http://thepsychologicalrecord.siuc.edu/index.html.

Palmer, D. C. (1991). A behavioral interpretation of memory. In L. J. Hayes & P. N. Chase (Eds.), *Dialogues on verbal behavior* (pp. 261–279). Reno, NV: Context Press.

Parsons, J. A., Taylor, D. C., & Joyce, T. M. (1981). Precurrent self-prompting operants in children: Remembering. *Journal of the Experimental Analysis of Behavior, 36* 253–266. doi: 10.1901/jeab.1981.36-253

Peterson, L. R., & Peterson, M. J. (1959). Short-term retention of individual items. *Journal of Experimental Psychology, 58*, 193–198. doi: 10.1037/h0049234

Sargisson, R. J., & White, K. G. (2001). Generalization of delayed matching to sample following training at different delays. *Journal of the Experimental Analysis of Behavior, 75*, 1–14. doi: 10.1901/jeab.2001.75-1

Saunders, R. R., Chaney, L., & Marquis, J. G. (2005). Equivalence class establishment with two-, three-, and four-choice matching to sample by senior citizens. *The Psychological Record, 55*, 539–559. Retrieved from http://thepsychologicalrecord.siuc.edu/.

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

Sidman, M., Stoddard, L. T., Mohr, J. P., & Leicester, J. (1971). Behavioral studies of aphasia: Methods of investigation and analysis. *Neuropsychologia, 9*, 119–140. doi: 10.1016/0028-3932(71)90038-8

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*, 5–22. doi: 10.1901/jeab.1982.37-5

Stromer, R., & Mackay, H. A. (1996). Naming and the formation of stimulus classes. In T. R. Zentall & P. M. Smeets (Eds.), *Stimulus class formation in humans and animals* (pp. 221–252). Amsterdam, The Netherlands: Elsevier.

Torgrud, L. J., & Holborn, S. W. (1989). Effectiveness and persistence of precurrent mediating behavior in delayed matching to sample and oddity matching with children. *Journal of the Experimental Analysis of Behavior, 52*, 181–191. doi: 10.1901/jeab.1989.52-181

Vaidya, M., & Smith, K. N. (2006). Brief report: Delayed matching-to-sample training facilitates derived relational responding. *Experimental Analysis of Human Behavior Bulletin, 24*, 9–16. Retrieved from http://www.eahb.org/NewSitePages/BulletinHomepage.htm.

White, K. G. (1985). Characteristics of forgetting functions in delayed matching to sample. *Journal of the Experimental Analysis of Behavior, 44*, 15–34. doi: 10.1901/jeab.1985.44-15

White, K. G. (2013). Remembering and forgetting. In G. Madden (Ed.), *APA Handbook of Behavior Analysis* (Vol. 1, pp. 411–437). Washington, DC: American Psychological Association.

Wixted, J. T. (1989). Nonhuman short-term memory: A quantitative reanalysis of selected findings. *Journal of the Experimental Analysis of Behavior, 52*, 409–426. doi: 10.1901/jeab.1989.52-409