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Training Conditional Discriminations with Fixed and Titrated Delayed Matching-to-Sample in Children

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In a series of experiments, we investigated the effects of delayed matching-to-sample (DMTS) on responding in accordance with stimulus equivalence in children. In Experiment 1, 20 participants were assigned to either 3 s or 6 s DMTS. The overall outcome showed high yields of derived responding but did not support a superiority of longer delays seen in some studies with adults. In Experiment 2, we arranged 3 s and 6 s titrating delayed matching-to-sample (TDMTS) procedures to see whether a gradual adjustment of delays based on participants' performance would be more effective in establishing the conditional discriminations and responding in accordance with stimulus equivalence. The results showed that fixed delays were most effective. In Experiment 3, ten participants experienced TDMTS from 1.5 to 3 s. This procedure facilitated the establishment of AC trials in initial training but did not reduce the overall number of trials required to establish baseline discriminations or affect responding in accordance with stimulus equivalence. The results are discussed in light of results obtained with adults, stimulus control involved in simultaneous and delayed matching, and precurrent behavior.

Key words: stimulus equivalence, delayed matching-to-sample, titrating delayed matching-to-sample, children

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Stimulus equivalence is defined as stimulus substitution and refers to classes of stimuli where the members involved are mutually interchangeable and where class membership is not a result of primary stimulus generalization (Green & Saunders, 1998). Research on stimulus equivalence is of particular interest because it has been repeatedly demonstrated that previously unrelated stimulus relations can arise without direct training (e.g., Lazar, Davis-Lang, & Sanchez, 1984; Saunders, Wachter, & Spradlin, 1988; Sidman, 1971; Sidman & Cresson, 1973; Spradlin, Cotter, & Baxley, 1973). Matching-to-sample procedures are (MTS) the most often used arrangement within equivalence research. The minimum arrangement required to study the emergence of novel responding in MTS tasks is to test for derived responding subsequent to the establishment of two interrelated conditional discriminations in two experimenter-defined classes with three members. If the stimuli involved in each experimenter-defined class share the properties of reflexivity, symmetry, and transitivity in subsequent tests for derived stimulus relations, stimulus equivalence is inferred.

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In other words, equivalence classes do not exist and cannot be measured directly, but abstractions are inferred based on performance in a test where participants are exposed to new stimulus-stimulus combinations. If participants, subsequent to the establishment of AC and BC relations, can match each stimulus in the stimuli set to itself, this is defined as reflexivity. Selecting A in the presence of C and B in the presence of C is defined as symmetry, and selecting B in the presence of A and A in the presence of B is defined as combined transitivity and equivalence.

In a matching-to-sample procedure (MTS), a response to the sample stimulus is followed by the presentation of two or more comparison stimuli. A comparison choice produces a programmed consequence. A correct comparison choice is followed by a reinforcing event or some kind of affirmative consequence. An incorrect response is followed by either some kind of corrective consequence or an inter-trial interval. If both the sample stimulus and comparison stimuli are present when the selection response occurs, the procedure is referred to as simultaneous matching-to-sample. Alternatively, a response to the sample stimulus can make it disappear and be followed by a delay before comparison stimuli are presented. In this arrangement, the selection response occurs in the absence of the sample stimulus, and the procedure is referred to as delayed matching-to-sample (DMTS). DMTS is frequently used to study remembering, both with identity and non-identity tasks. The typical finding in identity matching in non-humans is that matching accuracy decreases with longer delays (e.g., Sargisson & White, 2001; Sargisson & White, 2007; Urcuioli, 1985). This is often interpreted as diminished control by the sample stimulus. However, in a classic study, Blough (1959) found that two pigeons maintained high matching accuracy with longer delays. Blough observed that, in these subjects, behavior similar to rehearsal occurred just before the presentation of comparison stimuli. The behavior was initially irrelevant for the task but was accidentally reinforced and brought under control of the sample stimulus. Similarly, Parson, Taylor, and Joyce (1981) found that children who were taught sample specific behaviors in pre-training immediately acquired accurate matching performance when exposed to a DMTS task. Children who were taught non-specific sample behavior did not acquire matching accuracy or did so only gradually. Furthermore, Torgrud and Holborn (1989) found that 5-year-old children were unable to maintain accurate matching performance in delays above 2 s unless they were taught sample specific behaviors prior to exposure for delayed oddity matching.

Most research on stimulus equivalence has been arranged as simultaneous matching. Lately, a few studies have investigated the differential effects of simultaneous matching and DMTS in equivalence tasks. For example, Saunders, Chaney, and Marquis (2005) found that elderly participants experiencing a 0 s delay showed higher yields of derived responding than participants experiencing simultaneous matching. Furthermore, it was found that the 0 s DMTS was most effective in establishing conditional discriminations. Some researchers have investigated the effects of different delays on the probability of responding in accordance with stimulus equivalence. Arntzen (2006) arranged a series of experiments to investigate the effects of simultaneous matching and DMTS with different delays. In Experiment 1, participants were exposed to a many-to-one (MTO) training procedure. Half of the participants experienced a series of experimental conditions starting with simultaneous matching and followed by 0-, 2-, and 4 s delays, and the other half of the participants started with 4 s delays followed by 2- and 0 s delayed and, finally, simultaneous matching. The results of Experiment 1 showed that the probability of responding in accordance with stimulus equivalence increased as a function of longer delays.

In Experiment 2 and 3, he arranged a one-to-many (OTM) training structure. The experiments started with simultaneous matching, followed by 0-, 2-, and 4 s DMTS in Experiment 2, and 0-, 3-, and 9-s DMTS in Experiment 3. All the participants responded in accordance with equivalence. In a fourth experiment, participants who responded in accordance with stimulus equivalence when exposed to simultaneous matching and 0 s DMTS did not when distracter tasks were presented in the test. Similarly, Vaidya and Smith (2006) arranged a group design and found that participants experiencing 8 s DMTS had a higher outcome on symmetry trials than those of participants experiencing 0- and 2 s delays.

In a later study, Arntzen, Galaen, and Halvorsen (2007) expanded knowledge on the effects of DMTS by arranging 0-, 6-, and 12- s delays. They used an OTM training structure and a combined within- and between-subject design. Ten participants experienced the different delays in ascending order, and ten participants experienced the delays in descending order. The authors found an order effect of repeated training and testing in that all participants responded in accordance with equivalence in the last condition independent of the order of the delays. Taking both conditions into account, 19 out of 20 participants responded in accordance with equivalence in 0-, 6-, and 12 s DMTS. Summarized, the results of previous studies indicate that imposing a delay between the removal of the sample stimulus and presentation of the comparison stimuli generate high yields of responding in accordance with stimulus equivalence. DMTS arrangements can contribute to illuminate the kind of stimulus control and behavioral processes involved when verbal competent subjects serve as participants.

All of the aforementioned studies on the effects of DMTS in equivalence tasks were conducted with adult participants. We have not been able to find any studies on equivalence research where children have been exposed to DMTS with delays above 0 s. Therefore, we wanted to investigate the effects of DMTS with delays above 0 s on the establishment of conditional discriminations and responding in accordance with stimulus equivalence with children. Arntzen (2006) and Arntzen et al. (2007) arranged combined within- and between-subject designs where participants experienced different delay lengths in conditional discrimination training before a test for derived relations. As mentioned above, the retention intervals in these studies ranged from 0 to 12 seconds. Such designs are time-consuming and could be difficult to do with children as participants. To prevent possible “fatigue” effects and participant dropout, we arranged a group design where participants experienced either 3 s or 6 s delay. Retention intervals of 3 s and 6 s were arranged because it was within the range of earlier studies in adults and based on earlier DMTS experiments with children in our lab (Arntzen & Lian, 2007).

Experiment 1

The purpose of the present experiment was to investigate the effects of 3 s and 6 s DMTS on the probability of responding in accordance with equivalence in children.

Method

Participants. Twenty typically developing children, 13 girls and 7 boys, six to ten years of age, were voluntarily recruited in an elementary school. The participants were in 2nd to 4th grade. Parents filled out a consent form before the start of the experiment. None of the participants had any former experience with the stimuli involved in this study or with being participants in experiments. When recruited, the participants were told that the experiment was about learning and that stimuli would be presented on a computer as a type of game. They were also told that the approximate duration of the experiment was three hours, that the actual length depended on the number of correct responses, and that they would be offered some breaks. Furthermore, they were informed that the experimenter was not going to provide any cues or instructions after the onset of the experiment. They were also told that they could withdraw from the experimental session at any time. When the session was finished, each participant was thanked and debriefed.

Design. The participants were randomly assigned to one of two experimental groups. Ten participants experienced 3 s fixed delays and ten participants experienced 6 s fixed delays.

Setting and apparatus. The experimental sessions were conducted during school hours, and all participants finished the training and test within two days. An experimental room was arranged at the school and up to two participants performed the task at a time. Interior walls were arranged to form two 5 sq. ft. cubicles. Two Compaq nc6320 personal computers with 1828 MHz Intel Centrino® processors were used and placed so that the participants were facing the wall during experiments. The software was developed by PsychFusion Software in collaboration with the second author. The room was also equipped with a workstation for the experimenter, and the experimenter was present in the room during all experiments.

Stimuli. The stimuli used in this experiment were Arabic, Cyrillic, Greek, and Hebrew letters, as shown in Figure 1. In the MTO training structure, the C-stimuli served as nodes. All stimuli were displayed in a 4.6 x 3 inch click-sensitive area, in black with a white background. The click-sensitive areas surrounding the stimuli were invisible to the participants. Sample stimuli were presented in the middle of the screen and comparison stimuli were presented in the corners of the screen, leaving one corner blank. Sample stimuli were presented in random order within a training block, and the position of comparison stimuli was varied from trial to trial. The computer screen was 15.4 in and the distance from the center of the sample stimuli to the center of the comparison stimuli was 5.4 in.

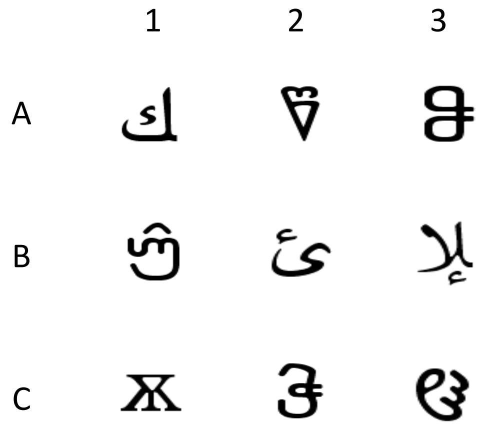

Figure 1. The figure shows stimulus set and experimenter defined classes. The numbers in Row 1 indicate class assignment and the letters in Column 1 indicate different class members. The C-stimuli served as node in all experimental conditions.

Correct comparison choices were followed by the Norwegian words for "correct," "well done," and "nice." Incorrect comparison choices were followed by the Norwegian word for "incorrect" displayed on the screen. All programmed consequences were displayed in blue letters in the middle of the screen for 1 second. In addition, the total number of correct scores was presented in the lower right corner of the screen for each trial. For each 50th correct comparison choice, the participants earned a sticker and attached it to a paper medal. The paper medals with earned stickers were taken home after the children completed the experiment. The stickers and paper medals were administered by the experimenter, while the presentation of all other stimuli was computer-controlled and administered.

Instructions. The following instructions were displayed in Norwegian and read aloud by the experimenter at the onset of the experiment:

> In a moment a sign will appear in the middle of the screen. Clicking on the sign will make it disappear and three other signs will appear

in the corners of the screen. Choose one of these by clicking it. If you choose the correct symbol "correct," "yes," "well done" and the like will be displayed on the screen. If you choose an incorrect one, "incorrect" will be displayed on the screen. During some stages of the experiment, the computer will NOT tell whether your choices are correct or incorrect. Please do your best to get everything correct. Thanks for participating and good luck!

If participants asked task-specific questions regarding the experiment, the relevant part of this instruction was repeated, or they were told, "You are doing fine; just keep on working." No other instructions or cues regarding the task were provided.

Conditional discrimination training. Six conditional discriminations were established using an MTO training procedure. Each trial started with the presentation of a sample stimulus in the middle of the screen.

Table 1. *Experimental phases*

Experimental Phases	Trial types	Accuracy criterion	Min no of trials
Day 1			
Serialized training			
AC trials	A1C1C2C3, A2C1C2C3, A3C1C2C3	8 out of 9	9
BC trials	B1C1C2C3, B2C1C2C3, B3C1C2C3	8 out of 9	9
Mixed training	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	36
Consequence thinning			
75% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
50% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
25% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
0% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
Day 2			
Mixed training	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	36
Consequence thinning			
75% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
50% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
25% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
0% probability	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3	16 out of 18	18
Test			
	A1C1C2C3, A2C1C2C3, A3C1C2C3, B1C1C2C3, B2C1C2C3, B3C1C2C3		54
	C1A1A2A3, C2A1A2A3, C3A1A2A3, C1B1B2B3, C2B1B2B3, C3B1B2B3,	17 out of 18	
	A1B1B2B3, B1A1A2A3, A2B1B2B3, B2A1A2A3, A3B1B2B3, B3A1A2A3	17 out of 18	

Note. The table shows the training and test phases in the experimental conditions. Underlined letter and number in the second column denotes the correct comparison choice for each trial type.

A mouse click to the sample stimulus removed the stimulus and was followed by a blank screen for 3 or 6 s before the presentation of three comparison stimuli. Comparison stimuli appeared in a random position in three corners of the screen. During the establishment of conditional discriminations, a correct comparison choice was followed by the Norwegian word for "correct," and an incorrect comparison choice was followed by the Norwegian word for "incorrect" displayed in the middle of the screen. Programmed consequences were displayed for 1 s, and the inter-trial interval was 500 ms. The mouse marker position was reset to the upper left corner of the click-sensitive area for sample stimuli at the start of each trial. Table 1 shows an overview of the different training phases, the trial types in each phase, mastery criteria, and the minimum number of trials per phase. Conditional discriminations were introduced in a serialized way, meaning that all AC relations (A1C1C2C3, A2C1C2C3, and A3C1C2C3) were established before the BC trials (B1C1C2C3, B2C1C2C3, and B3C1C2C3) were trained separately. The participants then experienced mixed training (all AC and BC trials presented in the same phase) with programmed consequences for each trial. When all conditional discriminations were established at a minimum of 16 out of 18 correct trials, the programmed consequences were thinned to 75% probability in the next training block and to 50%, 25%, and 0% probability for the following blocks. The last phase, with no programmed consequences for a comparison choice, was followed by the test block (see Table 1).

The accuracy criterion necessary to proceed to the next training phase was a minimum of 8 out of 9 correct trials in the serialized phases and 16 out of 18 correct comparison choices in the mixed training and in phases with concequence thinning. If the mastery criterion was not met in one block, the training phase was repeated until the criterion was reached. All experiments were accomplished within two days.

Test arrangement. The test condition was arranged as simultaneous matching. Symmetry and equivalence trial types (C1A1A2A3, C2A1A2A3, C3A1A2A3, C1B1B2B3, C2B1B2B3, C3B1B2B3 and A1B1B2B3, B1A1A2A3, A2B1B2B3, B2A1A2A3, A3B1B2B3, B3A1A2A3) were presented intermixed in random order with directly trained conditional discriminations interspersed to control for maintenance. The latter trial types will be referred to as maintenance of conditional discriminations (MCD) in the following. None of the trial types were followed by programmed consequences in test conditions. Each trial type was presented three times, yielding a total of 54 test trials, and no programmed consequences were arranged in the test conditions. The equivalence criterion was at least 17 of 18 correct comparison choices for symmetry-consistent and equivalence-consistent trial types separately. The participants who did not respond in accordance with equivalence and who did not have at least 17 out of 18 correct for the maintenance of conditional discriminations were excluded from the experiment.

Recordings and dependent measures. All data were registered by the software, i.e., which trial type was presented, comparison choice, and whether the comparison choice was in accordance with the experimenter-defined classes or not. The number of training trials, test trials, and symmetry and equivalence indices were summed up by the software for each participant. The dependent measures in this experiment were the number of participants responding in accordance with stimulus equivalence, symmetry and equivalence properties, and the number of training trials above the minimum.

Results and Discussion

Eight participants experiencing 3 s and seven participants experiencing 6 s delays responded in accordance with equivalence, as shown in Table 2. Two participants experiencing 3 s fixed delays, Participants 7016 and 7017, reached the criteria for neither the symmetry nor the equivalence property. Participant 7040, experiencing 6 s fixed delays, did not respond to the criterion for either the symmetry or the equivalence property. Participants 7031 and 7035, also experiencing 6 s fixed delays, responded to the criterion for the symmetry property but not for the equivalence property.

The median number of trials above the minimum requirement was 279 for the 3 s condition and 324 s for the 6 s condition. The individual results are shown in Table 2. Participant 7020 had 603 trials above the minimum requirement and the highest number of trials in the 3 s condition. Participant 7018, experiencing 3 s delays, had the lowest number of trials with 81 trials above the minimum requirement. In the 6 s condition, Participant 7037 had the highest number of trials with 648 trials above the minimum requirement, and Participants 7032 and 7034 had the lowest number of trials with 153 above the minimum requirement. Figure 2 shows the mean number of trials

Table 2. *Results 3 and 6 s delays*

Participants				Training		Test		
#	Gender	Age	Grade	Trials	Errors	MCD	SY	EQ
				3 s delays				
7010	f	7y 2m	2	270	126	**18/18**	**18/18**	**18/18**
7011	f	9y 10m	4	108	128	**18/18**	**18/18**	**17/18**
7012	m	7y 11m	3	234	82	**18/18**	**18/18**	**18/18**
7013	m	8y 9m	3	324	165	**17/18**	**17/18**	**18/18**
7015	f	7y 6m	2	252	80	**18/17**	**17/18**	**17/18**
7018	m	8y 4m	3	81	42	**18/18**	**18/18**	**18/18**
7019	f	9y 0m	3	288	141	**18/18**	**17/18**	**17/18**
7020	f	8y 5m	3	603	266	**18/18**	**18/18**	**18/18**
7016	f	7y 5m	2	306	184	**17/18**	15/18	12/18
7017	f	7y 7m	2	396	191	**18/18**	15/18	15/18
				6 s delays				
7032	f	8y 11m	3	153	95	**18/18**	**17/18**	**17/18**
7033	m	9y 7m	4	549	335	**18/18**	**18/18**	**18/18**
7034	m	7y 10m	2	153	63	**17/18**	**18/18**	**17/18**
7036	f	7y 8m	2	315	166	**18/18**	**18/18**	**17/18**
7037	f	8y 3m	3	612	277	**17/18**	**18/18**	**18/18**
7038	m	7y 4m	2	333	141	**18/18**	**18/18**	**17/18**
7039	m	9y 8m	4	378	211	**18/18**	**17/18**	**18/18**
7031	f	8y 2m	3	459	212	**18/18**	**17/18**	13/18
7035	f	7y 11m	3	261	125	**18/18**	**18/18**	9/18
7040	m	8y 10m	3	315	166	**18/18**	14/18	15/18

Note. MCD = maintenance conditional discriminations, SY = symmetry trials, EQ = equivalence trials. Trials report the number of trials above minimum. Bold numbers denotes test performance in accord with criterion.

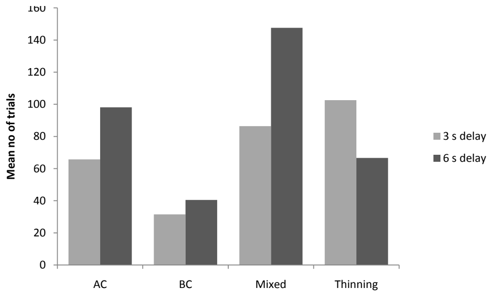

Figure 2. The figure shows the mean number of trials above minimum per training phase.

above the minimum for each of the training phases. The 3 s fixed condition established AC and BC conditional discriminations in fewer trials than the 6 s condition, and the difference between 3- and 6 s delays is most clear in AC- and mixed training. In the thinning phases, the mean number of trials above the minimum was higher for the 3 s delays than for the 6 s delays. The results show that the overall equivalence outcome was high and supports the findings in Arntzen (2006) and Arntzen et al. (2007) regarding the effects of DMTS on responding in accordance with stimulus equivalence. In the present experiment, eight participants responded in accordance with symmetry in the 3 s fixed delay and seven participants did so in the 6 s fixed delay.

The present results on responding in accordance with equivalence do not support the notion of the superiority of longer delays with adult participants as reported in Experiment 1 in Arntzen (2006). Furthermore, although the overall performance on tests for derived relations for participants experiencing fixed delays in the present experiment is high, it is somewhat lower than for adult participants experiencing delays above 2 s (Arntzen, 2006; Arntzen et al., 2007). Similar results were seen in earlier experiments in our lab (Arntzen & Lian, 2007; Lian, 2007). Torgrud and Holborn (1989) found that matching accuracy in children decreased when delays above 2 s were employed unless participants were taught sample specific behaviors. This is consistent with results obtained outside the behavior analytic domain. For example, Chelonis, Daniels-Shaw, Blake, and Paule (2000) investigated performance in a delayed matching-to-sample task in 674 children aged 5 to 13. The results suggest that younger children were less accurate than older children after short delays and also indicate a greater decrease in accuracy as delays increased. One possible interpretation of the present results as compared to the results for adults is that verbally competent adults have an extended history with problem-solving tasks and a more complex repertoire of verbal precurrent behavior than children. If the delay between the offset of the sample stimulus and presentation of comparison stimuli facilitates such behavior, one would actually expect the higher frequency of correct responding in adults.

In a DMTS procedure, the delay can either remain constant across all trials or be gradually changed across trials, and we asked whether a gradual increase in delays would be more effective in establishing the conditional discriminations. One procedure for gradually changing delays is the titrating delayed matching-to-sample procedure (TDMTS). Ferraro, Francis, and Perkins (1971) arranged a TDMTS procedure using non-identical stimuli with children from 5-11 years of age. In this experiment, the participants first experienced pre-training starting with 0 s delays and titrating in 1 s steps up to 2 s delays. In the experimental phase, the participants experienced a titrated procedure for 60 trials where the delay increased or decreased in 2 s steps. The initial experimental condition started at a 2 s delay. Two successive correct matches increased the existing delay by 2 seconds, while one incorrect response reduced the existing delay by 2 seconds. The results showed that the average delay reached corresponded to chronological age and that children above ten years of age were able to maintain accurate matching in delays longer than 40 s, while children under five years of age did not maintain accurate matching at delays longer than 0 seconds. A gradual adjustment in delay based on the participants' performance might be an effective way to establish conditional discriminations involved in equivalence tasks and might also influence responding in accordance with stimulus equivalence.

Experiment 2

The purpose of the present experiment was to investigate the effects of arranging 3 s and 6 s titrating delays on the establishment of conditional discriminations and responding in accordance with stimulus equivalence and to compare the results for the titrated conditions with the results for the fixed delays in Experiment 1. Furthermore, we wanted to address the possibility that some variables other than the fixed and titrated delays might have influenced the results and arranged two control conditions with 100 ms fixed and titrated delays. 100 ms is a very short delay, and we would not expect different results whether the delays were fixed or titrated. If, however, the two control conditions yield different results, we will have to conclude that some unintended variables have influenced the results.

Method

Participants. Twenty typically developing children, 13 girls and 7 boys, were voluntarily recruited in the same elementary school as in Experiment 1. The participants were in grade 2 to 4, six to ten years old, and were assigned to either 3 s or 6 s titrated delay groups. In addition, eight participants were assigned to one of two control conditions: 100 ms fixed and 100 ms titrated delays. None of the participants had any former experience with the stimuli involved in this study or with being participants in experiments. The participants received the same information about the experiment as participants in Experiment 1, and parents filled out a consent form. When the experimental session was finished, each participant was thanked and debriefed.

Design. Experiment 1's 3 s and 6 s fixed delays and the 3 s and 6 s titrated delays in the present experiment constituted the 4 experimental conditions in the study, with 10 participants in each condition. In addition, we arranged a control condition where 100 ms fixed delays were compared to 100 ms titrated delays, with 4 participants in each group.

Setting and apparatus. Experiments were conducted in the same room as in Experiment 1, and the same computers and software were used.

Stimuli and instructions. The stimuli set was identical to the set used in Experiment 1, and the same stimulus-stimulus relations were established in the conditional discrimination training. The same instructions used for Experiment 1 were read aloud at the onset of each experiment.

Conditional discrimination training. The training phases, training structure, conditional discrimination procedure, and ITI interval were the same as in Experiment 1 except that a response to the sample in the first trial was followed by a 0 s delay and that the minimum number of trials in the mixed phase was 36 in Experiment 1 with fixed delays and 54 in the present experiment with titrating delays. The accuracy criterion necessary to proceed to the next training phase was also the same as in Experiment 1, implying a minimum of 8 out of 9 correct trials in the serialized phases and 16 out of 18 correct comparison choices in the mixed training and thinning phases. If the mastery criterion was not met in one block, the training phase was repeated until the criterion was reached. All experiments were accomplished within two days.

Titration procedures. In the titrated conditions (see overview in Table 3), the initial delay was 0 s and the titrating was arranged in twelve steps. The step size was 250 ms in the 3 s titrated condition and 500 ms in the 6 s titrated condition.

Table 3. *Procedure for adjusting the delays*

3 s titrated	6 s titrated
Initial trial at 0 ms delay Min no of trials: 3 Criterion not met: 0 ms delay continued Criterion met: delay increased in next block	**Initial trials at 0 ms delay** Min no of trials: 3 Criterion not met: 0 ms delay continued Criterion met: delay increased in next block
250 ms delay Min no of trials: 3 Criterion not met: 0 ms delay in next block Criterion met: Delay increased in next block	**500 ms delay** Min no of trials: 3 Criterion not met: 0 ms delay in next block Criterion met: Delay increased in next block
500 ms delay Min no of trials: 3 Criterion not met: 250 ms delay in next block Criterion met: Delay increased in next block	**1000 ms delay** Min no of trials: 3 Criterion not met: 500 ms delay in next block Criterion met: Delay increased in next block
750 ms delay Min no of trials: 6 Criterion not met: 500 ms delay in next block Criterion met: Delay increased in next block	**1500 ms delay** Min no of trials: 6 Criterion not met: 1000 ms delay in next block Criterion met: Delay increased in next block
1000 ms delay Min no of trials: 6 Criterion not met: 750 ms delay in next block Criterion met: Delay increased in next block	**2000 ms delay** Min no of trials: 6 Criterion not met: 1500 ms delay in next block Criterion met: Delay increased in next block
1250 ms delay Min no of trials: 6 Criterion not met: 1000 ms delay in next block Criterion met: Delay increased in next block	**2500 ms delay** Min no of trials: 6 Criterion not met: 2000 ms delay in next block Criterion met: Delay increased in next block
1500 ms delay Min no of trials: 6 Criterion not met: 1250 ms delay in next block Criterion met: Delay increased in next block	**3000 ms delay** Min no of trials: 6 Criterion not met: 2500 ms delay in next block Criterion met: Delay increased in next block
1750 ms delay Min no of trials: 6 Criterion not met: 1500 ms delay in next block Criterion met: Delay increased in next block	**3500 ms delay** Min no of trials: 6 Criterion not met: 3000 ms delay in next block Criterion met: Delay increased in next block
2000 ms delay Min no of trials: 6 Criterion not met: 1750 ms delay in next block Criterion met: Delay increased in next block	**4000 ms delay** Min no of trials: 6 Criterion not met: 3500 ms delay in next block Criterion met: Delay increased in next block
2250 ms delay Min no of trials: 6 Criterion not met: 2000 ms delay in next block Criterion met: Delay increased in next block	**4500 ms delay** Min no of trials: 6 Criterion not met: 4000 ms delay in next block Criterion met: Delay increased in next block
2500 ms delay Min no of trials: 6 Criterion not met: 2250 ms delay in next block Criterion met: Delay increased in next block	**5000 ms delay** Min no of trials: 6 Criterion not met: 4500 ms delay in next block Criterion met: Delay increased in next block
2750 ms delay Min no of trials: 3 Criterion not met: 2500 ms delay in next block Criterion met: **Delay at 3000 ms for remaining trials**	**5500 ms delay** Min no of trials: 3 Criterion not met: 5000 ms delay in next block Criterion met: **Delay at 6000 ms for remaining trials**

Note. The table shows the procedure for adjusting the delays. The accuracy criterion to proceed to the next training phase is the same as in Experiment 1.

Table 4. *Training phases in the control conditions (100 ms) and experimental conditions (3 and 6 s)*

Control conditions 100 ms fixed and titrated delays	**Experimental conditions** 3- and 6 s fixed and titrated delays
Day 1	**Day 1**
Serialized training AC and BC trials	*Serialized training AC and BC trials*
Mixed training	*Mixed training*
Thinning of programmed consequences	*Thinning of programmed consequences*
Day 2	**Day 2**
Serialized training AC and BC trials	*Mixed training*
Mixed training	*Thinning of programmed consequences*
Thinning of programmed consequences	*Test*
Test	

The adjustment of delays was based on the participants' performance with a requirement of at least 80% correct responses per block. In the serialized training phases, one titrating block was 3 trials, while in the mixed training and thinning, one titrating block was 6 trials. If participants responded at 80% correct or higher for one training block, the delay was increased by one step for the next block. If the responding was lower than 80%, the delay for the next block was decreased by one step. The delays were titrated to the maximum value in the mixed training phase and remained constant at 3 s or 6 s throughout the thinning phases.

Control conditions. In the fixed condition, the delay between the removal of the sample stimulus to the presentation of the comparison stimuli was 100 ms for all trials in the conditional discrimination training, while the titrated delays started at a 0 s delay and titrated in 8 ms steps based on the participants' performance. If participants had a minimum of 80% correct trials for one training block, the delay was increased by 8 ms and, if a participant did not reach the criteria, the delay was decreased by 8 ms for the next training block. The participants in the control conditions experienced serialized training on both days of the experiment (see Table 4 for the differences between training procedures in the control and experimental groups).

Test arrangement. The test conditions in the titrating and control conditions were arranged in the same way as the test conditions for Experiment 1.

Dependent measures. The dependent measures in this experiment were trials above the minimum in conditional discrimination training and the number of participants responding in accordance with stimulus equivalence.

Statistical analyses. For the statistical analysis, we used a two-way unrelated ANOVA to evaluate the effects of the four experimental conditions on the number of trials above the minimum. Two-way ANOVA was also used to evaluate the effects of the experimental conditions on responding in accordance with stimulus equivalence.

Results and Discussion

The results for the participants experiencing 100 ms fixed and titrated delays in the control conditions are shown in Table 5. Two participants responded in accordance with stimulus equivalence in both conditions. One participant in the fixed condition, Participant 7004, who failed to meet the criterion for the maintenance of conditional discriminations and responding in accordance with stimulus equivalence, was excluded from the experiment. The mean number of trials above the minimum to establish the conditional discrimination relations was 421 for both the 100 ms fixed and titrated delays. The results in the control condition yield no clear differentiation between the fixed and titrated delays regarding the probability of responding in accordance with stimulus equivalence or the number of trials necessary to establish the conditional discriminations to the criterion.

Five participants experiencing 3 s titrated delays and three participants experiencing 6 s titrated delays responded in accordance with stimulus equivalence, as seen in Table 6. Among the participants experiencing 3 s titrated delays, Participants 7024 and 7027 reached the criterion for the symmetry property but not the criterion for the combined transitivity/equivalence property. The participants who failed to meet the symmetry

Table 5. *Individual Results Control Conditions*

Participants				Training		Test		
#	Gender	Age	Grade	Trials	Errors	MCD	SY	EQ
				100 ms fixed				
7003	m	7y 2m	2	405	204	**17/18**	**17/18**	**17/18**
7005	f	7y 8m	3	666	308	**16/18**	**18/18**	**17/18**
7001	f	9y 3m	4	459	168	**18/18**	16/18	12/18
7002	m	9y 6m	4	153	25	**18/18**	16/18	14/18
				100 ms titrated				
7007	m	7y 2m	2	333	213	**17/18**	**17/18**	**18/18**
7008	f	8y 8m	4	594	213	**17/18**	**18/18**	**17/18**
7006	m	9y 5m	4	243	86	**18/18**	16/18	16/18
7009	f	7y 11m	3	513	231	**17/18**	11/18	10/18

Note. MCD = maintenance conditional discriminations, SY = symmetry trials, EQ = equivalence trials. Trials report the number of trials above minimum. Bold numbers denotes test performance in accord with criterion.

criterion, Participants 7023, 7028, and 7029 also failed to meet the equivalence criterion. Experiencing 6 s TDMTS, Participant 7041, 7046, 7049, and 7050 reached the criterion for the symmetry property but not the criterion for equivalence. Participants 7047 and 7048 failed to reach the criterion for both the symmetry property and the equivalence property. Participant 7043 did not reach the criterion for the symmetry property but did reach the criterion for the equivalence property. In comparing the results for Experiments 1 and 2, a two-way unrelated ANOVA of the number of participants responding in accordance with stimulus equivalence was carried out on the variance on the data. The main effect of the fixed versus titrated delays ($F_{1,36}$ = 5.313, p = 0.027, partial η^2 = 0.129) was statistically significant, while the main effect of the delay duration ($F_{1,36}$ = 0.976, p = 0.330, partial η^2 = 0.026) and the interactions of the fixed/titrated and delay duration ($F_{1,36}$ = 0.108, p = 0.744, partial η^2 = 0.003) were not.

The median number of trials above the minimum in conditional discrimination training was 428 in the 3 s titrated condition and 531 in the 6 s titrated condition. In the 3 s titrated condition, Participant 7024 had the highest score with 837 trials above the minimum, while Participant 7022 had the lowest score with 240 trials above the minimum. In the 6 s titrated condition, Participant 7047 had the highest score with 1251 trials above the minimum and Participant 7043 had the lowest score with 279 trials above the minimum. Figure 3 shows the mean number of trials above minimum in each training phase. In comparing the results for Experiments 1 and 2, a two-way unrelated ANOVA showed that significant effects were obtained for fixed versus titrated delays ($F_{1,36}$ = 11.15, p = 0.002, partial η^2 = 0.236), but not for the retention interval ($F_{1,36}$ = 3.93, p = 0.055, partial η^2 = 0.098) or the interactions of the fixed/titrated and retention intervals ($F_{1,36}$ = 0.89, p = 0.352, partial η^2 = 0.024). The number of trials required to reach the criterion in the initial training phases for fixed and titrated delays is shown in Figure 4. The figure shows that the difference between the fixed and titrated conditions is most clear in the AC phase.

Table 6. *Individual Results Experiment 2*

Participants				Training		Test		
#	Gender	Age	Grade	Trials	Errors	MCD	SY	EQ
				3 s titrated				
7021	f	6y 10m	2	603	211	**18/18**	**18/18**	**18/18**
7022	f	10y 1m	4	240	130	**18/18**	**17/18**	**17/18**
7025	f	7y 6m	2	459	241	**18/18**	**18/18**	**17/18**
7026	f	7y 8m	2	396	161	**18/18**	**17/18**	**17/18**
7030	m	9y 10m	4	306	108	**18/18**	**17/18**	**17/18**
7023	f	8y 1m	3	468	217	**18/18**	10/18	11/18
7024	m	7y 10m	3	837	296	**18/18**	**17/18**	15/18
7027	f	8y 5m	3	576	191	**18/18**	**18/18**	16/18
7028	m	7y 8m	2	261	97	**17/18**	16/18	16/18
7029	f	8y 9m	3	252	90	**18/18**	15/18	16/18
				6 s titrated				
7042	f	9y 11m	4	630	218	**17/18**	**17/18**	**18/18**
7044	f	8y 9m	3	504	192	**18/18**	**18/18**	**17/18**
7045	f	7y 0m	2	432	219	**18/18**	**18/18**	**17/18**
7041	f	6y 11m	2	621	220	**17/18**	**18/18**	15/18
7043	m	7y 8m	2	279	75	**18/18**	15/18	**17/18**
7046	f	8y 5m	3	1008	177	**18/18**	**17/18**	13/18
7047	m	7y 11m	3	1251	249	**17/18**	15/18	10/18
7048	m	9y 4m	4	522	203	**18/18**	14/18	12/18
7049	m	8y 11m	3	486	236	**17/18**	**17/18**	15/18
7050	f	8y 5m	3	540	209	**18/18**	**17/18**	14/18

Note. MCD = maintenance conditional discriminations, SY = symmetry trials, EQ = equivalence trials. Trials report the number of trials above minimum. Bold numbers denotes test performance in accord with criterion.

The purpose of Experiment 2 was to investigate whether a gradual adjustment of the delays would be more effective than the fixed delays in Experiment 1 when it comes to establishing conditional discriminations and responding in accordance with stimulus equivalence. A control condition was arranged to assess the possibility that variables other than the explicitly arranged ones had influenced the results. The 100 ms fixed and titrated delays were not differentiated regarding the number of trials required to establish baseline relations or responding in accordance with stimulus equivalence. Thus, the results of the control condition did not indicate that some unintended variable or combination of variables had influenced the results.

A comparison of the results of Experiments 1 and 2 showed that three more

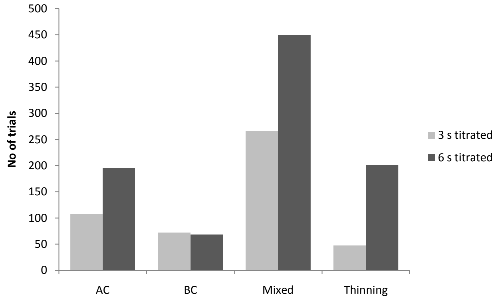

Figure 3. The figure shows the mean number of training trials above minimum per training phase.

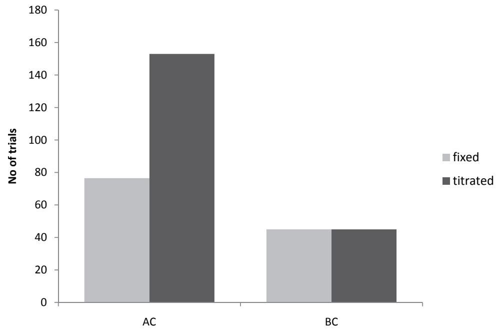

Figure 4. The figure shows the median number of trials in initial training for the fixed and titrated conditions.

participants responded in accordance with stimulus equivalence after 3 s delays than after 6 s delays. Although the 3 s and 6 s conditions did not reach significance levels in the present experiments, the results do not support the notion of the superiority of longer delays as seen in Experiment 1 in Arntzen (2006) and in tests for symmetrical relations in Vaidya and Smith (2006).

We initially thought that a gradual increase in delays based on participant performance would be an effective procedure to establish accurate matching performance. Contrary to our prediction, the fixed DMTS training established the conditional discriminations in fewer trials and generated higher yields of responding in accordance with stimulus equivalence. The differentiation of the two conditions was statistically significant on both dependent variables. The participants in titrating conditions experienced maximum retention intervals of 3 s and 6 s during the last part of the mixed training and in the thinning of programmed consequences, while the participants in fixed conditions experienced 3 s or 6 s delays in all training phases. This implies that the total number of trials with the maximum delay was higher for participants experiencing fixed delays. It is possible that an extended experience with maximum delays in the fixed condition influenced the results on responding in accordance with stimulus equivalence.

Regarding the number of trials required to establish baseline relations, the titrating delays required higher number of trials above the minimum. The participants in titrating conditions experienced delays from 0 s in the initial training to the highest value in the last training phases, while participants in fixed conditions experienced maximum delays throughout all training phases. In the AC training phase, the participants in the titrating conditions experienced delays between 0 s and 1.5 s depending on how accurately they responded, while the participants in fixed conditions experienced delays of constant duration of either 3 s or 6 s. The results show that the median number of trials in the AC training was twice as high for titrating delays as for fixed delays. Studying the stimulus control involved in DMTS with neurological patients, Sidman (1969) found that stimulus control shifted as a function of increasing delays from 0 s to 32 s. While the comparison choice at simultaneous matching and 0 s delays was controlled by the sample stimulus, the comparison choice at delays above 0 s was controlled both by the sample stimulus and features of the comparison display. Taking this into account, it is possible that titrating steps from 0 s delays in the initial training retarded the establishment of stimulus control in the initial training. We wanted to investigate this possibility by arranging TDMTS with initial delays above 0 s in a third experiment.

Experiment 3

The purpose of this experiment was to investigate whether TDMTS with initial delays of 1.5 s would reduce the number of incorrect comparison choices in the AC training compared to the results of Experiment 2. Furthermore, we wanted to see whether initial delays above 0 s would affect the number of trials required to establish conditional discriminations to the criterion and responding in accordance with stimulus equivalence.

Method

Participants, setting and apparatus, instructions, and stimuli. Ten children in 2nd and 3rd grade, eight girls and two boys, six to nine years of age, were voluntarily recruited from the same elementary school as the participants in Experiments 1 and 2. The experimental setting and apparatus, instructions provided at the onset of the experiment, stimuli involved, and programmed consequences were identical to those used in Experiments 1 and 2. All participants completed the experiments in two days, and the participants were offered a debriefing when the task was finished.

Conditional discrimination training. As in Experiments 1 and 2, the conditional discriminations were established in an MTO training structure. The training phases, programmed consequences, and ITI interval were the same as those of Experiments 1 and 2. The accuracy criterion necessary to proceed to the next training phase was also the same as in Experiments 1 and 2, implying a minimum of 8 out of 9 correct trials in the serialized phases and 16 out of 18 correct comparison choices in the mixed training and thinning phases. If the mastery criterion was not met in one block, the training phase was repeated until the criterion was reached. All experiments were accomplished within two days.

Titration procedure. The titrating procedure was the same as in Experiment 2 except that the initial delays in training were 1.5 s and titrated in 12 steps to a maximum delay of 3 s. The step size was 125 milliseconds. As in Experiment 2, the criterion for adjustment of the delays was 80%. The delays reached the maximum value during the mixed training and remained at the maximum throughout the thinning phases regardless of the participants' performance.

The test arrangements were the same as in Experiments 1 and 2, with participants experiencing symmetry and equivalence relations in random order with maintenance conditional discriminations interspersed. No programmed consequences were arranged in the test.

Results and Discussion

The individual results for Experiment 3 are presented in Table 7. The table shows that six out of ten participants responded in accordance with stimulus equivalence. Participants 7052 and 7055 reached the criterion for the symmetry property but not the criterion for the equivalence property. Participants 7057 and 7058 did not reach the criteria for the symmetry or the equivalence property.

The median number of trials above the minimum in the conditional discrimination training was 472. The individual results are presented in Table 7 and reveal marked between-subject variability. Participants 7053 and 7060 had the highest number of trials, 1260 and 1070 trials, respectively, while Participant 7056 had 81 above the minimum and the lowest number of trials. The median number of trials in the initial training phases is shown in Figure 5. The figure shows that the mean number of trials was 63 in the AC training and 33 in the BC training.

A comparison of the results for the fixed and titrated delays revealed a markedly higher number of trials in the AC training in the titrated conditions, and the main purpose of the current experiment was to investigate whether introducing delays above 0 s in the initial training would improve performance in the AC training.

Table 7. *Individual Results Experiment 3*

Participants				Training		Test		
#	Gender	Age	Grade	Trials	Errors	MCD	SY	EQ
7051	f	6y 10m	2	387	125	**18/18**	**18/18**	**18/18**
7056	f	7y 8m	2	81	37	**18/18**	**17/18**	**17/18**
7053	m	8y 3m	3	1260	356	**18/18**	**18/18**	**18/18**
7054	f	7y 6m	2	387	173	**18/18**	**18/18**	**18/18**
7059	f	7y 11m	2	432	159	**18/18**	**18/18**	**18/18**
7060	f	8y 1m	3	1076	491	**17/18**	**18/18**	**17/18**
7055	m	7y 0m	2	477	167	**17/18**	**17/18**	15/18
7052	f	8y 1m	3	640	144	**18/18**	**17/18**	16/18
7057	f	8y 5m	3	693	226	**18/18**	16/18	14/18
7058	f	7y 8m	2	467	222	**17/18**	10/18	9/18

Note. MCD = maintenance conditional discriminations, SY = symmetry trials, EQ = equivalence trials. Trials report the number of trials above minimum. Bold numbers denotes test performance in accord with criterion.

Titrating delays from 1.5 s reduced the number of trials in the AC training markedly compared to titrating from 0 s.

On the other hand, titrating delays from 1.5 to 3.0 seconds did not improve the number of trials for all training phases, as the median number of trials above the minimum was higher in the present experiment than in titrating from 0 s to 3 s and 6 s in Experiment 2. One more participant responded in accordance with stimulus equivalence in the present experiment

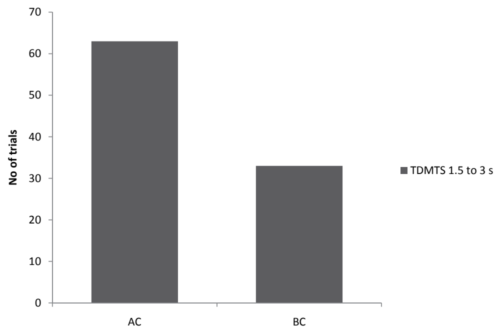

Figure 5. The figure shows the median number of trials in initial training.

compared to the participants experiencing titrating from 0 s to 3 s in Experiment 2. The difference is marginal, however, and we have to conclude that titrating from 1.5 s to 3 s did not improve responding in accordance with stimulus equivalence.

General Discussion

The purpose of Experiment 1 was to investigate the effects of DMTS on the probability of responding in accordance with stimulus equivalence in children. The overall performance showed high frequencies of derived responding and supports the results in previous studies with adult participants. Titrating delays in twelve steps from 0 s to 3 s and from 0 s to 6 s in Experiment 2 and from 1.5 s to 3 s in Experiment 3 generated lower yields of responding in accordance with equivalence than the fixed delays. In addition, the participants experiencing titrating delays had a higher number of trials in training than the participants experiencing fixed delays. Previous studies in adults have shown that DMTS generates high yields of derived responding.

For example, Saunders et al. (2005) found that senior citizens experiencing DMTS had higher yields of responding in accordance with stimulus equivalence than participants experiencing simultaneous matching. Additionally, some studies have indicated that an experience with longer delays is more effective than an experience with short delays in generating responding in accordance with stimulus equivalence (Arntzen, 2006) or symmetry alone (Vaidya & Smith, 2006). Contrary to these results in adults, the present data do not support the notion of the superiority of longer delays. Although the overall performance is high, it is somewhat lower than the results reported in adult participants experiencing delays above 2 s (Arntzen, 2006; Arntzen et al., 2007). Similar results were seen in earlier experiments in our lab (Arntzen & Lian, 2007; Lian, 2007). One possible interpretation of this tendency is that adult participants have a more complex repertoire of problem-solving behavior and an extended history with conditional discriminations. Arntzen (2006) arranged a within-subject design, while in the present experiment, we used a between-subject design. It is also possible that the different arrangement has influenced the contradicting results regarding the effects of longer delays. Further evidence is needed to support the tendency of a higher probability of responding in accordance with stimulus equivalence in adults than in children indicated here, preferably by recruiting both children and adults to participate in the same experimental procedures. Applying the "silent dog" method as described by Hayes (1986) in future experiments could shed light upon the different kinds of verbal behavior involved in equivalence tasks.

Furthermore, except for the Vaidya and Smith (2006) study, all studies involving DMTS training mentioned here applied an MTO or OTM training structure. Research on stimulus equivalence has shown that equivalence outcome subsequent to matching-to-sample training varies depending on how the conditional discriminations involved in training are related. There seems to be a general agreement that a linear training structure is the least effective arrangement, while contradicting results have been reported regarding the differential effects of the MTO and OTM training structures. Some studies have provided data suggesting that MTO is the most effective training structure (Saunders, Saunders, Williams, & Spradlin, 1993; Saunders et al., 2005; Saunders, Drake, & Spradlin, 1999), while other studies have shown that the OTM training structure is more effective (Arntzen, 2004; Arntzen & Holth, 1997, 2000). Some of the studies reporting the superiority of MTO have included children as participants (Arntzen & Vaidya, 2008; Saunders et al., 1999). Since equivalence studies with adults have used MTO and OTM training structures associated with high yields on test for derived relations, we decided to use an MTO in present experiment. However, using a training structure that is associated with high yields of responding in accordance with stimulus equivalence might interfere with the experimental conditions. Future research should arrange DMTS training in a linear structure to isolate the possible effects of the MTO and OTM training structures. Furthermore, arranging a training structure usually associated with lower yields of responding in accordance with stimulus equivalence could potentially differentiate the effects of different retention intervals to a higher degree than was the case in the present experiments.

The study of Sidman (1969) indicated that stimulus control shifted from exclusive control by the sample stimulus in simultaneous matching and a 0 s delay to combined or even joint control by the sample stimuli and the features of comparison displayed at delays above 0 s. In that study, comparison choice at 32 s delays was almost exclusively controlled by the features of the comparison display. In simultaneous matching-to-sample, the participant has the opportunity to look back and forth between the sample stimulus and comparison stimuli, and such behavior could occasion a correct comparison choice. In a DMTS task, comparison choice occurs in the absence of the sample stimulus and, according to Sidman (1969), the change in stimulus control must be a consequence and not a cause of diminished stimulus control. In other words, at delays above 0 s, the absence of the sample stimulus sets the stage for other kinds of stimulus control. The retention intervals of certain duration "forces" subjects to perform some kind of behavior, or a sequence of behaviors, to "remember" the sample at the time of comparison selection. As observed by Blough (1959), behavior occurring during the retention interval might be accidently reinforced, and the stimuli products of such behavior can acquire discriminative control over a selection response. Skinner (1968) described precurrent behavior as behavior that changes the contingencies or the organism in such a way that it produces new discriminative stimuli, signaling that a given response will lead to reinforcement. Such behavior can be verbal, but other topographies should be considered as well.

Contrary to our initial prediction, TDMTS was less effective than fixed delays both in establishing conditional discriminations and in generating derived relations. One possible interpretation of this result is that the initial delays of 3 s and 6 s provide increased opportunities to perform some kind of precurrent behavior in the initial training compared to the 0 s delays in the first phases in the TDMTS conditions. When the initial delays were 1.5 seconds in Experiment 3, it markedly reduced the number of incorrect responses and AC relations were established to the criterion more rapidly. In addition, the constant delay throughout all phases of training provides increased opportunities to repeat and maintain such behavior.

The variables entailed in TDMTS procedures can be manipulated in several ways, and other procedural arrangements can reveal different results. Additionally, very few studies on TDMTS in human participants have been published, and different titrating arrangements make comparison across studies difficult. For example, Ferraro et al. (1971) arranged TDMTS in an identity matching task where the delay increased by 2 s after two consecutive correct trials and decreased by 2 s after one incorrect trial. Sidman, Stoddard, Mohr, and Leicester (1971) used a TDMTS where one correct response increased the delay and one incorrect response decreased the delay by 4 s. In the present experiments, we arranged 12 titrating steps where the step size was 500 ms in 0 s to 6 s delays and 250 ms in 0 s to 3 s delays. Due to software restrictions, the accuracy criterion to increase the delays was 3 out of 3 correct trials in AC and BC training and a minimum of 5 out of 6 correct comparison choices in subsequent training phases. Even though the accuracy criteria to proceed to the next training phase was a minimum of 16 out of 18 trials (8 out of 9 in AC and BC training), it could be that requiring a higher number of correct responses in each titrating step would be more effective in the initial training. Further studies on TDMTS in humans should aim to clarify the effects of the different variables entailed in TDMTS procedures, including the initial delay value, titrating step size, and requirement for correct responding before delays are adjusted.

One limitation of the present experiments is the difference in the minimum number of trials required in the fixed and titrated conditions. As described in the methods section, the minimum number of trials was lower in the fixed procedure than in the titration procedure. We have used the number of trials above the minimum as a dependent measure to eliminate the differences in results caused by the descriptive operants, but choosing a dependent measure that equalizes procedural differences does not rule out the possibility that these differences may have influenced the participants' performance. Further studies on the effects of fixed versus titrated delays should, therefore, control for the number of trials across conditions by, for example, yoking the schedules for two participants.

All summed up, the DMTS training with fixed delays in Experiment 1 generated high yields of responding in accordance with stimulus equivalence. The findings supported the results of studies with adult participants. The fixed DMTS procedure was more effective in generating derived relations than TD-MTS. Moreover, the fixed delays established baseline conditional discriminations more rapidly than the titrating delays from 0 s to 3 s and from 0 s to 6 s. When the initial delay was increased to 1.5 s in Experiment 3, the number of trials in AC training was reduced to the same levels as the fixed delays. The titrating delays from 1.5 s to 3 s in Experiment 3 did not, however, improve the number of trials in all training phases or responding in accordance with stimulus equivalence. In discussing the role of verbal behavior in the establishment of equivalence classes, Stromer and Mackay (1996) predicted that, if verbal behavior plays a role in the establishment of equivalence classes, one should expect high frequencies of responding in accordance with stimulus equivalence subsequent to DMTS training. The present results support this prediction. It should be emphasized that, although, the present results indicate that an increased opportunity to perform precurrent behavior facilitates both the establishment of conditional discriminations and responding in accordance with stimulus equivalence, the present data does not provide evidence that such behavior is necessary to establish equivalence relations. Future research on the effects of DMTS in equivalence tasks should arrange LS training structure to control for possible confounding effects of OTM and MTO training structure. Applying the "silent dog" method can shed light upon the role of verbal behavior in the establishment of responding in accordance with stimulus equivalence, and might reveal differences in precurrent behavior in adults and children. Furthermore, arranging distracting tasks in DMTS tasks might be a fruitful way to broaden our knowledge on different kinds of precurrent behavior involved in DMTS performance.

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