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FACILITATING RELATIONAL FRAMING IN CHILDREN AND INDIVIDUALS WITH DEVELOPMENTAL DELAY USING THE RELATIONAL COMPLETION PROCEDURE

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The Relational Completion Procedure is effective for establishing same, opposite and comparative derived relations in verbally able adults, but to date it has not been used to establish relational frames in young children or those with developmental delay. In Experiment 1, the Relational Completion Procedure was used with the goal of establishing two 3-member sameness networks in nine individuals with Autism Spectrum Disorder (eight with language delay). A multiple exemplar intervention was employed to facilitate derived relational responding when required. Seven of nine participants in Experiment 1 passed tests for derived relations. In Experiment 2, eight participants (all of whom, except one, had a verbal repertoire) were given training with the aim of establishing two 4-member sameness networks. Three of these participants were typically developing young children aged between 5 and 6 years old, all of whom demonstrated derived relations, as did four of the five participants with developmental delay. These data demonstrate that it is possible to reliably establish derived relations in young children and those with developmental delay using an automated procedure.

Key words: derived relational responding, relational completion procedure, autism spectrum disorder, mouse click, touch screen, humans

A by-now vast literature has amassed showing that when a number of interrelated conditional discriminations are trained, derived (untaught) relations often emerge (Dymond & Roche, 2013). To study derived relational responding, researchers typically use conditional discrimination procedures, which involve presenting arbitrary and physically dissimilar stimuli, usually in a match-to-sample (MTS) format. For example, the choice of a particular comparison, denoted B, is reinforced in the presence of sample stimulus A, (i.e., A–B) and on other trials selecting comparison stimulus C is reinforced in the presence of sample stimulus A (i.e., A–C). It is then likely that relations will emerge between B–A, C–A (mutual entailment) and B–C and C–B (combinatorial entailment), in the absence of any further training. When this occurs, the stimuli are said to have formed a relational frame of sameness or coordination (Hayes, Barnes-Holmes, & Roche, 2001) or *equivalence* relations (Sidman, 1994). This basic effect has now been demonstrated in numerous empirical investigations using various stimuli, procedures, and populations.

In order to explain the development of the ability to derive relations, relational frame theory (RFT) focuses on the history of reinforcement for bidirectional responding across multiple exemplars. Learning to derive may proceed as follows: Both elements of a relation are explicitly trained across many examples (e.g., A is related to B, and B is related to A and both instances of relating are reinforced; C is related to D and D is related to C and both reinforced and so on); subsequently this history of reinforcement generalizes with the result that a derived relation emerges without explicit reinforcement (e.g., relating X to Y is explicitly reinforced, but relating Y to X is derived without reinforcement). Thus, according to RFT, the ability to derive relations is itself a learned behavior: an overarching, purely functional operant (Healy, Barnes-Holmes & Smeets, 2000; Stewart, McElwee, & Ming, 2013).

If derived relating is operant behavior, then it follows that a multiple exemplar intervention (MEI) should facilitate derivation. Supporting evidence for this position comes from a number of studies demonstrating the emergence of derived relations following a MEI. Berens and Hayes (2006), for instance, conducted a study with four 4–5-year-old typically developing

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children who were unable to perform a series of problem solving tasks involving more- and less-than relations. Following a MEI, the participants demonstrated arbitrary comparative relations and these skills generalized across stimuli and across trial types. (Barnes-Holmes, Barnes-Holmes, Roche and Smeets (2001a, 2001b) and Gómez, Lopez, Martin, Barnes-Holmes, and Barnes-Holmes (2007) found that a MEI facilitated the emergence of mutually entailed (i.e., symmetric) relations for participants who had initially failed to derive these relations.

The majority of research on derived relational responding has utilized MTS procedures. There are relatively few published studies describing alternatives to this procedure when human participants are used (e.g. Cullinan, Barnes-Holmes & Smeets, 2001; Fields et al., 1997) but using other procedures may reveal novel findings about derived relations (Barnes-Holmes Barnes-Holmes, Smeets, Cullinan, & Leader, 2004). One such procedure, based to some extent on the MTS format, is the Relational Completion Procedure (RCP; Dymond, Roche, Forsyth, Whelan & Rhoden, 2007, 2008; Dymond & Whelan, 2010). Dymond et al., (2007) used this procedure to train *same* and *opposite* relations. The participants' task was to "complete" a three-stimulus sequence. On the upper half of the screen, the sample stimulus appeared first on the left, followed by a contextual cue (an arbitrary stimulus denoting either a *same* or *opposite* relation) in the middle, and then a blank box on the right. Up to five comparison stimuli, one of which was the correct comparison stimulus, then appeared in the lower portion of the screen. The participants completed the three-stimulus sequence by dragging and dropping one of the comparisons into the blank box and clicking a button to confirm their selection, the latter facilitating derived relations (Dymond, Ng, & Whelan, 2013). The combination of stimulus presentation order, the physical response of dragging and dropping, and making a confirmatory response after every selection resulted in fewer trials to meet the training criteria and a higher overall percentage yield of participants passing derived relations tests on the RCP compared to traditional matching-to-sample based paradigms (Dymond & Whelan, 2010). Further studies with *same* and *opposite* (Dymond et al., 2013) and *more than/less than* relations (Munnelly, Freegard, & Dymond, 2013) have replicated and extended these promising findings.

Several studies have demonstrated a link between verbal ability and the ability to derive (e.g., Barnes, McCullagh, & Keenan, 1990; O'Hora, Pelaez, & Barnes-Holmes, 2005) and a growing body of research suggests that interventions that teach derived relational responding improve verbal ability (see Barnes & Rehfeldt, 2013 for an overview). For example, Rosales and Rehfeldt (2007) taught two individuals with developmental delay to request items to complete a chained task. In one situation, participants could request a spoon by presenting a picture of a spoon in order to make Kool-Aid. Subsequent conditional discrimination training resulted in a derived relation between the picture of a spoon and printed text of the word "SPOON". Participants could then present the text in exchange for a spoon, in order to complete the chain. Thus, the participants' verbal repertoires were expanded, without explicitly training the behavior of requesting using printed words. Given the potential benefits of establishing derived relations, a key priority is to develop an efficient method for delivering such interventions. While initial results with the RCP are promising, no study has evaluated this procedure among individuals with a limited verbal repertoire. Here, we used a computerized version of the RCP, in combination with a MEI (when required), to establish derived relations in individuals with autism and in typically developing young children.

EXPERIMENT 1

Method

Participants, Apparatus, and Setting

Experiment 1 included nine participants (all male; age range 5–18 years old), all with a diagnosis of Autism Spectrum Disorder (ASD). All participants were verbal and, with the exception of Participant 9, had moderate to severe delays in both receptive and expressive language. Additional participant information may be found in Table 1.

Prior to the study commencing, consent forms were obtained from the participants or their parents or guardians, and they were given an information and debriefing sheet. Participants were given verbal information about the study and were told that they could end a session

Table 1

Experiment 1: Participants' characteristics, language delay status, and formal language assessment results.

Participant	Age	Language Delay	Language development percentile (if applicable)
1	5	Yes	34[a]
2	6	Yes	10[a]
3	18	Yes	<5[b]
4	17	Yes	<5[b]
5	18	Yes	<69[c]
6	12	Yes	4[d]
7	9	Yes	16[d]
8	12	Yes	1[d]
9	6	No	37[d]

[a]Wechsler Preschool & Primary Scale of Intelligence - Third UK Edition.
[b]Adaptive Behavior Assessment System-Second Edition.
[c]Wechsler Intelligence Scale for Children: Third Edition
[d]British Picture Vocabulary Scale: Second Edition.

at any time and begin again in the next scheduled session or take a short break if they felt tired. Participants were trained and tested individually, in a quiet room at school (Participants 3, 4, & 5) or at home, with the experimenter seated behind the participant, and not interacting with the participant. Participants completed the task on a laptop computer equipped with a 17-in. monitor. The computer presented all stimuli and recorded all responses. Sessions lasted between 15–45 min, dependent on participant performance.

Procedure

The study consisted of three phases: baseline, conditional discrimination training, and testing for derived relations (described below). If a participant failed a test for derived relations, he/she completed the MEI. This consisted of explicitly training all possible relations, followed by a test of these trained relations (i.e., in extinction). If participants passed this test, they moved on to a novel stimulus set and the phases began again. Experiment 1 trained and tested two 3-member sameness networks (i.e., equivalence classes). Each stimulus set is named alphanumerically for the benefit of the reader (e.g., A1, B1, C1; A2, B2, C2); participants were unaware of these labels.

RCP Protocol

Before the first session, the participants were told that they were going to play a game on the computer and the task was demonstrated by the experimenter. Participants 1–5 were competent and familiar with the use of a computer and mouse, and Participants 6–9 employed a touch screen. During all training and testing phases the computer screen was divided into two areas, the top half blue and the bottom half gray. At the onset of a trial, a sample stimulus appeared on the left upper half of the screen and a blank box appeared on the right upper half of the screen. After a 1-s delay, two comparison stimuli appeared on the bottom half of the screen. The participants' task was to drag and drop one of the comparison stimuli to the blank box. Once the stimulus had been "dropped", a trial confirmation screen appeared in which the top half of the screen remained the same and two buttons appeared in the bottom half of the screen displaying the options "Start again" (in red) or "Finish trial" (in green; the confirmatory response). After the confirmatory response, the screen cleared and the sample and selected comparison were presented together along with the feedback ("correct" or "wrong") for 3 s. A 2-s intertrial interval (blank screen) followed. The order of trial types was randomized across blocks of trials (described below) and the positions of the comparison stimuli were randomly counterbalanced across trials.

Across participants, different categories of stimuli served as the A, B, and C stimuli. For participants 3–9, the stimuli were randomly assigned to two stimulus classes for the purposes of relational training and testing. Table 2 outlines the trained relations.

Baseline. Prior to this condition the experimenter explained to the participants that there would be no consequences for making onscreen selections but they should try to continue selecting pictures until the computer stopped presenting pictures. The participants were told to press "Start" to begin the session. Twenty-four trials were completed. Within these trials were two presentations each of the to-be-trained (A1–B1, A2–B2, A1–C1, A2–C2) and derived relations (B1–A1, B2–A2, C1–A1, C2–A2, B1–C1, B2–C2, C1–B1, C2–B2). Trials were conducted in the manner described above but without any consequences provided by the computer. This phase served to verify that the relations among the stimuli were unknown to the participants.

Conditional discrimination training. This phase began by training A–B and A–C relations using an errorless training procedure. Trial

Table 2
Experiment 1: Trained and tested relations, stimuli for Set 1, and correct responses.

Relation	Relation type	Sample	Correct comparison	Sample	Correct comparison	Sample	Correct comparison
		Participants 1–2		Participants 3–5		Participants 6–9	
A1–B1	Trained	Dog picture	DOG	PIM	ZEM	CUG	Cartoon1
A2–B2	Trained	Cow picture	COW	MAB	KET	PAF	Cartoon2
A1–C1	Trained	Dog picture	MADRA	PIM	NIB	CUG	Apple picture
A2–C2	Trained	Cow picture	BO	MAB	LAN	PAF	Popcorn picture

structure was as described above except that only the correct comparison was displayed at the bottom of the screen. Training was arranged in four-trial blocks whereby each relation (A1–B1, A2–B2, A1–C1, and A2–C2) was presented once. Two blocks of trials were completed.

In the next portion of this phase, two comparison stimuli were presented per trial, only one of which was correct. If the participant moved the correct comparison stimulus to the blank box, the screen displayed for 2 s a message such as "Very good [participant's name]", or "Well done [participant's name]". Incorrect responses were followed by the word "Wrong" (for 2 s), followed by a re-presentation of the same trial. The mastery criterion was four out of four trials correct (100%) over one block of trials. Next, feedback was gradually reduced across trial blocks each time the mastery criterion was met (75%, 50%, 25% and 0% reinforcement).

There were additional contingencies in place for certain participants. Participants 3–5 were able to obtain a preferred reinforcer (all chose internet access) on completion of a session. Participants 6–9 were given the opportunity to win a small prize for completion of a session. Participant 9 was identified in advance as displaying high levels of off-task behavior; as such, additional programmed contingencies of reinforcement were implemented. Firstly, correct responses were followed by the presentation of video clips in which the experimenter congratulated the participant. These were presented on a variable-ratio (VR) 2 schedule. Secondly, the experimenter presented a plate of marbles and a jar and explained that in order to obtain a prize, the participant would need to "win" marbles by responding to the tasks correctly. During the experiment, the researcher sat beside the participant and transferred the marbles from the plate to the jar on a VR3 schedule for correct responses. Following the transfer of all of the marbles from the plate to the jar the experimenter immediately said "Well done! You have won the prize" and presented the toy to Participant 9, who was then offered the opportunity to win another prize.

Test for derived relations. During this phase, the baseline procedures (24 trials assessing all trained and derived relations) were repeated with the exception that feedback was provided on half of the baseline trials. Participants demonstrated mastery if at least 90% of their selections on derived-relations test trials were correct. Participants who demonstrated mastery did not proceed to the next phase.

Multiple exemplar intervention (MEI). Participants who did not demonstrate mastery in the preceding test of derived relations completed a MEI, during which baseline/derived test procedures (i.e., utilizing the same stimuli) were repeated. However, in this phase, feedback was provided following each comparison stimulus selection. Blocks of 24 trials were repeated until the participant met or exceeded a 90% correct mastery criterion. For Participants 1 and 2 the first two blocks consisted of a sham MEI in which a number of unrelated conditional discriminations were trained (the conditional discriminations trained in the sham MEI were included in the MEI test phase, thus it was possible to reliably exceed 50% responding during this phase). The aim of this phase was to demonstrate that in the absence of MEI, derived relations would not emerge with additional exposure to the stimuli or time on task.

After the MEI mastery criterion was met, the same block of 24 baseline trials was presented without feedback. If accuracy fell below 90%, the MEI continued with the same set of stimuli and with feedback provided following every trial.

After participants met the MEI mastery criterion without feedback, the protocol began anew (i.e., from baseline) with an entirely new

set of stimuli (i.e., A1, B1, C1, A2, B2, C2). For Participant 1, the protocol was changed for the final two sets of stimuli following the fifth set. This was done to reduce time on task to reach criterion. Participant 1 became agitated and did not remain seated for the entire session. During these sets, the participant was first exposed to the baseline phase. He then went on to a train-only phase, which contained 32 trials to meet the criterion of 90%. Following this, he was exposed to a short train-and-test phase with no consequence fading and no errorless learning.

Results and Discussion

Figure 1 shows the percentage correct responses for all participants during the baseline and derived-relations test sessions. In the first test for derived relations Participants 6–8 met the mastery criterion and, therefore, did not require the MEI. The accuracy of derived relations for all other participants indicated that baseline training was not sufficient for the emergence of derived relations. Therefore, these participants progressed to the MEI.

Figure 1 also shows the scores for the MEI for all participants who completed this phase and Table 3 shows the number of trials to reach the mastery criterion for each participant in the MEI. Participants 3–5 and Participant 9 all met the mastery criterion of 90% correct following the MEI for Set 1 and therefore moved on to the next set of stimuli. Participants 1 and 2 failed to pass the test for derived relations following sham MEI with two stimulus sets. These participants were exposed to the MEI following their failure to demonstrate derived relations on the third stimulus set. Participants 1 and 2 passed the test for derived relations without the need to complete a MEI phase in Sets 6 and 5, respectively. Participant 3 established derived relations on Stimulus Set 2 and demonstrated this a second time on Set 3. Participant 4 completed three stimulus sets, and failed to

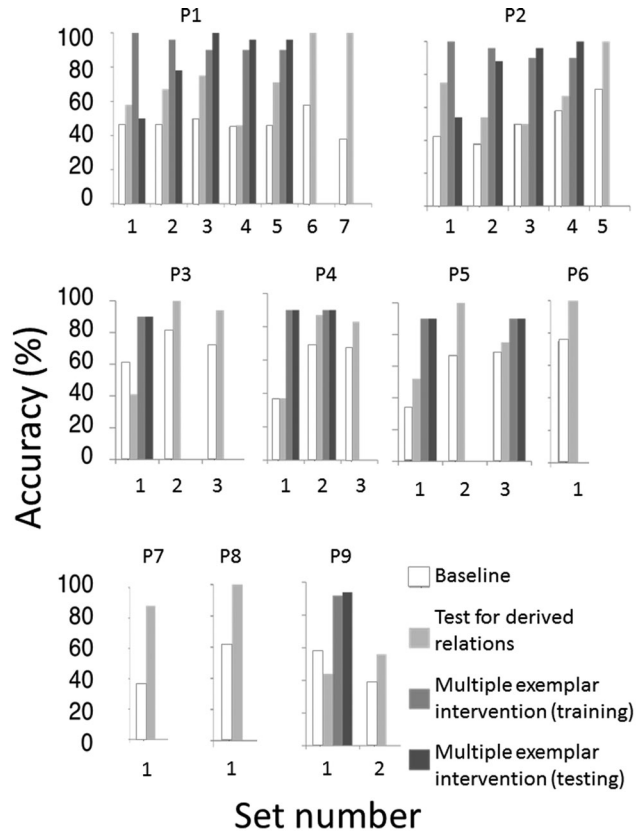

Fig. 1. Overall results for Participants 1–9 (Experiment 1).

Table 3

Number of trials required to reach criterion in each stimulus set during Experiment 1.

Stimulus Sets	Train & Test	MEI
Participant 1		
Set 1	72	72 (control)
Set 2	96	48 (control)
Set 3	232	48
Set 4	96	72
Set 5	100	48
Set 6	64	–
Set 7	64	–
Participant 2		
Set 1	100	48 (control)
Set 2	288	72 (control)
Set 3	56	72
Set 4	92	48
Set 5	56	–
Participant 3		
Set 1	110	270
Set 2	78	–
Set 3	98	–
Participant 4		
Set 1	110	216
Set 2	86	270
Set 2	82	54
Participant 5		
Set 1	94	270
Set 2	86	–
Set 3	106	270
Participant 6		
Set 1	64	–
Participant 7		
Set 1	104	–
Participant 8		
Set 1	52	–
Participant 9		
Set 1	78	137
Set 2	68	–

meet the criterion for establishing derived relations for any of the sets, although his percentage correct approximated the criterion on Sets 2 and 3; due to time constraints, this participant was unable to complete the MEI phase for Set 3. Participant 5 completed three stimulus sets and required the MEI on Sets 1 and 3; due to time constraints this participant did not continue. Likewise, because of time constraints, Participant 9 did not complete MEI after failing to demonstrate derived relations on Set 2.

Experiment 1 showed that the RCP procedure could be used to train and test the emergence of derived relations. It also demonstrated how a MEI can assist in the emergence of derived relations when training and testing are not sufficient. Experiment 2 aimed to demonstrate how, with the addition of a fourth stimulus to the relational network (i.e., A–B–C–D), the RCP could be used to establish derived relations in both young typically developing children (age range 5–6) and older children (age range 10–11) with developmental delay. The addition of an extra member to each network increased the number of derived relations from 16 to 36, and therefore represents a relatively large increase in complexity that more closely approximates the processes underlying natural language.

EXPERIMENT 2

Method

Participants, Apparatus, and Setting

There were eight participants in Experiment 2 (Participants 10–17; see Table 4). Participants 10–12 were all typically developing and Participants 13–17 had an official diagnosis of ASD. Sessions were conducted either in a quiet room in the participant's home (Participant 13) or at school in a quiet classroom (remaining participants). The computerized protocol used in Experiment 1 was employed again; Participants 10–12 used a mouse and Participants 13–17 employed a touch screen.

For Participants 10–12 each stimulus set consisted of pictures of animals (A stimuli), the name of the animal in the English language (B stimuli), the name of the animal in the Irish language (C stimuli) and the name of the animal in French (D stimuli). These participants all spoke English, and none spoke either Irish or French. For the remaining participants, each set consisted of nonsense syllables (A stimuli), pictures of cartoon characters (B stimuli),

Table 4

Experiment 2: Participants' characteristics, language delay status, and formal language assessment results.

Participant	Age	Language Delay	Language development Percentile[a] (if applicable)
10	5	No	Typically developing
11	6	No	Typically developing
12	5	No	Typically developing
13	10	No	74
14	10	No	30
15	10	Yes	6
16	10	No	68
17	11	No	96

[a]British Picture Vocabulary Scale: Second Edition.

Table 5

Experiment 2: Trained and tested relations, example stimuli, and correct responses.

Relation	Relation type	Sample example	Correct comparison	Sample example	Correct comparison
		Participants 10–12		Participants 13–17	
A1-B1	Trained	COW	BO	CUG	Cartoon1
A2-B2	Trained	DOG	MADRA	PAF	Cartoon2
A1-C1	Trained	COW	Picture cow	CUG	Apple picture
A2-C2	Trained	DOG	Picture dog	PAF	Popcorn picture
A1-D1	Trained	COW	la vache	CUG	Superman picture
A2-D2	Trained	DOG	le chien	PAF	Batman picture

pictures of food items (C stimuli) and pictures of Marvel© comic characters (D stimuli). The stimuli were randomly assigned to two stimulus sets for the purposes of relational training and testing. Table 5 outlines the relations that were trained.

Procedure

Baseline. For Participants 10–12 the procedure was identical to Experiment 1, with the exception that trials involving the D stimuli were also presented, resulting in a total of 48 trials in this phase (i.e., testing all possible relations). For Participants 13–17 the baseline procedure was identical to Experiment 1 because these participants were trained initially on three-member networks: Therefore, stimulus relations involving the 'D' stimuli were not assessed.

Conditional discrimination training. For the typically developing participants (10–12) two comparison stimuli were presented on each trial; for the participants with an ASD diagnosis (13–17) the errorless learning procedure (one comparison stimulus presented until the first mastery criterion was met) was used. Participants 10–12 were immediately exposed to conditional discrimination training designed to establish two 4-member sameness networks, whereas Participants 13–17 were first trained to establish two 3-member sameness networks (i.e., equivalence classes), as per Experiment 1. With the exception of Participant 16 (see below), all participants passed the test for derived relations following training with the first stimulus set, and thus none required a MEI. Following the successful tests for derived relations with 3-member networks, Participants 13–15 and 17 were then trained to establish two 4-member sameness networks. Training was arranged in six-trial blocks whereby each relation (A1–B1, A2–B2, A1–C1, A2–C2, A1–D1, and A2–D2) was presented once in a random order. An errorless training procedure (as per Experiment 1) was conducted for the first six-trial block during which trials were presented in a nonrandom sequence (A–B, A–C, then A–D). Following this initial block, trial types were presented in a random order. The mastery criterion for this phase was six out of six trials correct across two blocks of trials. Reinforcement density fading was identical to Experiment 1.

Derived relations testing. These phases were identical to Experiment 1, with the exception that there were 6 trained and 18 derived relations and each was presented twice in blocks of 48 trials. Due to experimenter error, Participant 13 received a derived relations test in which each relation was presented three times rather than twice.

Results and Discussion

Participant 16's test scores are not detailed here as he requested to leave the experiment prior to completing the conditional discrimination training phase (terminating after 127 trials) and therefore took no further part in the study. Figure 2 shows the percentage of correct responses for all participants in the baseline phase and during the test for derived relations. The baseline findings indicated that, for all but one participant, the specific to-be-trained and -tested skills involving the experimental stimuli were absent. The one exception was Participant 14 who responded at above criterion level accuracy (92%) across all relations during baseline. As a result and due to the arbitrary allocation of stimulus relations, the stimuli that served as B1 and B2 were switched prior to conditional discrimination training (e.g., Cartoon 1 served as B2 and Cartoon 2 served as B1). Thus, for Participant 14 the to-be-trained stimulus relations were assigned in accordance with baseline responding. The reassignment of

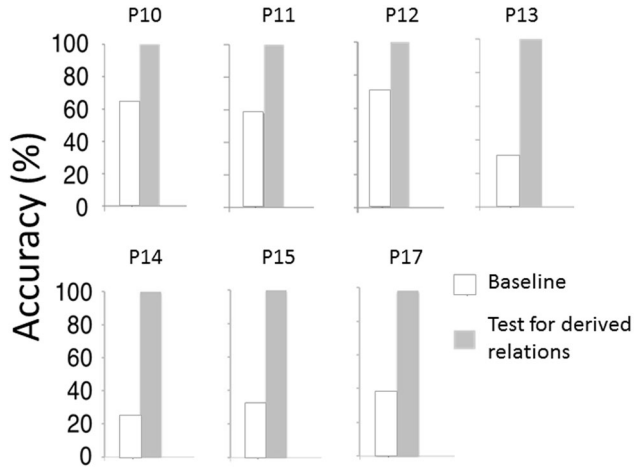

Fig. 2. Overall results for Participants 10–17 (Experiment 2).

stimulus relations for Participant 14 resulted in a pretest score of 25% (displayed in Fig. 2). Participant 12 also responded at higher than chance levels during baseline trials (71%). When these results were further broken down by trial type, they showed that Participant 12 responded at 100% for all A–C (English-pictures) relations. Table 6 displays the number of trials to criterion in Experiment 2.

Figure 2 highlights the derived test scores for all participants, which indicates that the conditional discrimination training employed was sufficient to establish derived relational responding for all participants, with the exception of Participant 16. As all participants passed the test for derived relations, a MEI was not required for any participants in Experiment 2.

General Discussion

The present experiments demonstrate that it is possible to reliably establish derived relations in developmentally delayed individuals and in young typically developing children: Heretofore, there has been a lack of derived relations research involving these populations. The participants in this study varied widely in their ages (range 5–18) and verbal ability (1st percentile of verbal ability to typically developing). In addition, the range of stimuli was highly varied, including Irish and French printed words, pictures of superheroes, of food, and of animals. MEI was included for participants who did not display derived relations following conditional discrimination training, and this training appeared to facilitate derived relational responding. Thus, the present study suggests that the RCP is a generalizable and robust method for training and testing derived relations.

Table 6

Number of train and test trials required to reach criterion during Experiment 2.

Stimulus Sets	3-Member	4-Member
Participant 10	–	114
Participant 11	–	96
Participant 12	–	168
Participant 13	56	120
Participant 14	72	96
Participant 15	56	96
Participant 17	52	96

Previous studies that used the RCP to establish derived relations (Dymond & Whelan, 2010) employed verbally able adults. To this end, the current set of results is notable for its high yield: 14 of 17 participants demonstrated derived relational responding, some following exposure to a MEI. Additional procedural factors may have facilitated the establishment of derived responding for individuals with ASD. For example, the errorless learning protocol eliminated initial errors, thereby providing a high rate of reinforcement from the beginning. The gradual reduction of reinforcement over the course of the conditional discrimination training likely attenuated any effects of a sudden change from high reinforcement during training to extinction during testing. The presentation of a small number of trials per session was employed to prevent boredom or fatigue. The current study

employed a baseline phase, in order to identify any preexisting relationships among stimuli. It is notable that not all participants responded at 50% correct during the baseline. An examination of the data showed that participants tended to consistently select a particular comparison given a particular sample stimulus throughout the baseline phase. For example, Participant 15 responded at 0% "correct" on all trials designated as directly trained or mutually entailed, whereas he responded at 100% correct on trials designated as one-node trials, yielding an overall performance of 33%.

Employing an automated procedure allowed for accurate, reliable and valid data collection. The computer program counterbalanced position of stimuli, ensured all stimuli were positioned correctly, and removed the possibility of experimenter cueing or human error. The computer program also required less staff to conduct a session, and additional data collectors were not required. The automated procedure also allowed participants to determine their own rate of trial presentation.

One potential criticism of Experiment 1 is that, following the first failure to pass the test for derived relations, subsequent successful derived performances were due to time on task and not due to the MEI per se. In an attempt to control for this possibility, we employed a sham MEI for Participants 1 and 2, in which unrelated conditional discriminations were presented. Our original intention was to expose the majority of participants to this control condition. However, an inordinate amount of training was required following the sham MEI procedure (e.g., 232 and 288 trials for P1 and P2, respectively). For this reason, and given the previous demonstration of the efficacy of MEI (Barnes-Holmes et al., 2001a, 2001b), we discontinued use of sham MEI as it placed an undue burden on the participants, with little apparent gain. Participants 1 and 2 both passed the test for derived relations following two exposures to the MEI.

Overall, the present findings (and others such as Luciano, Becerra and Valverde, 2007) further demonstrate that a MEI leads to emergent relational responding in participants who lack basic language skills. It is notable that the present study included formal tests of language ability, which is not typical in studies of derived relations in developmental delay (O'Donnell & Saunders, 2003). Our Experiment 1 data showed that the majority of participants with a formal diagnosis of language delay required multiple attempts and an MEI before they demonstrated emergent derived relations, whereas typically developing individuals and those in the normal range of verbal functioning (Experiment 2) did not.

The present data may have educational implications for children with autism: The present RCP protocol produces derived relational responding and presenting it via an automated program enhances its practicality. Ongoing work involves the combination of relational frames, established using robust protocols, with other behaviors, such as requesting, to broaden the behavioral repertoire and improve the functioning of individuals with developmental delay. Future research could examine changes at the neural level pre- and post-acquisition of the ability to derive relations (Whelan & Schlund, 2013), as this could yield insights into the neurobiology of language development.

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