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Facilitating derived requesting skills with a touchscreen tablet computer for children with autism spectrum disorder

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ABSTRACT

Two experiments were conducted employing derived relational responding and conditioned motivating operations to establish untaught mands with 11 children with autism spectrum disorder (ASD) who lacked a vocal repertoire. Following formal language assessments and preference assessments, a multi-stage automated protocol was implemented on touchscreen tablet computers. Children were first taught to mand by picture exchange for missing items necessary to play with a toy and then learned to conditionally relate the dictated names of the items to the corresponding pictures of the items (A-B training) and to relate the dictated names to the corresponding printed words (A-C training). Test probes, in the absence of reinforcement, were presented to determine whether or not participants would mand for the missing items using text exchange (hence demonstrating derived manding/requesting). Probes for spontaneous matching (B-C and C-B) and labeling (B-A and C-A) were also presented in both experiments, one of which employed a pretest/posttest design and the other a multiple probe across participants design. Across both experiments, all but one of the participants showed evidence of derived requesting and derived stimulus relations. Implications for research on high-tech devices for facilitating independent communication skills of children with ASD and for derived relational responding approaches to verbal operants are discussed.

1. Introduction

In his taxonomy of verbal behavior, Skinner (1957) defined the mand as "a verbal operant in which the response is reinforced by a characteristic consequence and is therefore under the functional control of relevant conditions of deprivation or aversive stimulation" (Skinner, 1957, p. 35). Manding or requesting allows the user to contact the social world of wants and needs and is an essential feature in promoting independent, functional communication skills across the developmental lifespan. Indeed, children with autism spectrum disorder (ASD) often lack the key behavioral flexibility with requesting

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demonstrated by their typically developing peers (Wahlberg & Jordan, 2001). Facilitating the development of untaught requests/mands is therefore a meaningful and worthy goal for early intervention programs; developing procedures that successfully demonstrate trained, and untrained, responding would also likely be of benefit to educators and caregivers.

Environmental conditions required for an instance of manding to occur are called establishing or motivating operations (Michael, 1982) and refer to the manipulation of variables to alter the momentary value of a reinforcer and the frequency of behaviors associated with that reinforcer (Laraway, Snycerski, Michael, & Poling, 2003; Michael, 1993). Michael (1993) distinguished between two types of establishing operations: conditioned (CEO) and unconditioned (UEO). The latter's value-altering effects are unlearned (e.g., the presence of heat increases the momentary value of a fan), while CEOs depend on individual learning histories (e.g., the presence of a lock on a cupboard establishes the reinforcing value of a key when access to food is valuable as a source of reinforcement; Langthorne & McGill, 2009). In educational and clinical settings, the CEO has long been found to be an effective means of teaching manding skills (e.g., Hart & Risley, 1975). For instance, one procedure to establish manding skills using the CEO is the *missing items protocol* (Carroll & Hesse, 1987; Marion, Martin, Yu, Buhler, & Kerr, 2012). This procedure involves contriving a state of deprivation by removing a vital part of something needed to enjoy a preferred item. For example, withholding a marble needed to enjoy playing with a marble run would set the occasion for the relevant mand (i.e., "may I have the marble?") to occur in order to play with the toy.

Recently, researchers have sought to synthesize mand-training procedures with research on derived relational responding as a means of facilitating untrained manding skills in people with ASD and other developmental disorders (Barnes & Rehfeldt, 2013; Rehfeldt & Barnes-Holmes, 2009). Derived relational responding refers to the outcome where, after being taught a series of interconnected conditional discriminations involving physically dissimilar (arbitrary) stimuli, the stimuli involved become related to each other in ways not explicitly trained. Sidman (1971) account of stimulus equivalence is an example of one such route to untrained learning outcomes. For example, if an individual is taught to conditionally relate dictated names of items to their corresponding pictures (i.e., A-B) and text (i.e., A-C), he or she may, without further reinforcement, correctly label the pictures (i.e., B-A) and text (i.e., C-A), which are referred to as symmetry relations, and match the pictures to the text (i.e., B-C) and the reverse (i.e., C-B), which is known as combined symmetry and transitivity or equivalence relations (Sidman, 1994).

Research on derived relational responding has mainly used match to sample (MTS) procedures in which choice of the correct comparison stimulus is reinforced in the presence of a specific sample stimulus. Other procedures, such as the computer-based Relational Completion Procedure (RCP), have been developed that more closely approximate linguistic-communicative episodes involving reading and completing sentences and in making requests (Dymond & Whelan, 2010; Munnelly, Freegard, & Dymond, 2013; Walsh, Horgan, May, Dymond, & Whelan, 2014). For instance, Walsh et al. (2014) adapted the RCP with the goal of establishing two, 3-member equivalence relations in individuals with ASD. During all phases, the computer screen was divided into two areas (the top half was blue and the bottom half was gray). Trials commenced with a sample stimulus appearing on the left upper half of the screen and a blank box appearing on the right upper half of the screen. Then, 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 comparison stimulus had been "dropped", participants could either cancel ("start again") or confirm ("finish trial") their response. After the confirmatory response, the screen cleared and the sample and selected comparison were presented together along with feedback before the inter-trial interval and another trial commenced. Walsh et al. found that seven of nine participants with ASD passed tests for derived equivalence relations using the RCP, while, in Experiment 2, four of the five participants with developmental delay demonstrated equivalence relations. These promising findings were obtained with exclusively visual, arbitrary (e.g., experimenter-determined) relations. It remains to be seen whether similar findings may be obtained with children with ASD with limited verbal abilities when both auditory and visual stimuli drawn from meaningful real-world objects or events are incorporated into the RCP.

The flexibility of the RCP for studying manding suggests considerable potential and also warrants further empirical attention. Indeed, synthesizing mand training procedures with instructional procedures for establishing derived relational responding allows one to study untrained or derived requesting (Halvey & Rehfeldt, 2005; Murphy & Barnes-Holmes, 2010; Rehfeldt & Root, 2005; Rosales & Rehfeldt, 2007). An instance of derived requesting is a request for an object or action that has not been reinforced in the past, is not the result of direct pairing with a reinforced mand, and does not physically resemble an object that previously reinforced the mand (generalization; Barnes-Holmes, Barnes-Holmes, & Cullinan, 2000). For example, if a child has received water by vocally requesting in English, for "water" and then the word water is conditionally related to the Welsh word for water, "dwr", a child subsequent request for "dwr" would exemplify a derived mand involving symmetry relations (assuming the influence of Pavlovian contingencies may be ruled out). Rehfeldt and Root (2005) examined derived requesting skills involving equivalence relations in three adults with severe intellectual disabilities and no functional requesting skills. Participants were initially taught to mand for preferred items using the Picture Exchange Communication System (PECS; Frost & Bondy, 2002). Following this, pretest probes were conducted to evaluate the extent to which participants were able to request those same items using text rather than pictures (which they were not). During these probes, five textual stimuli were placed on the top of the PECS book and the available preferred item was held up in front of the participant. Subsequent conditional discrimination training was conducted where participants learned to relate dictated names to corresponding pictures (A-B), then dictated names to corresponding printed words (A-C). Finally, posttest derived mand probes were initiated in an identical fashion to the pretest probes. All three participants requested using text during the post-test probes demonstrating the emergence of derived requesting.

A potential limitation of the Rehfeldt and Root (2005) study was that requests were made for present and visible preferred items, which may have caused ambiguity as to whether or not the derived requesting was exclusively under the control of the current MOs and not the preferred items themselves (i.e., tacts; Rosales & Rehfeldt, 2007). Essentially, it was unclear whether the participants were manding, for example for sandwiches, because they had learned that the text was indirectly related to the picture or because they were matching the object (sandwiches) to the text from their PECS book. In fact, participants' responding could more accurately resemble a matching task similar to matching pictures to text. Rosales and Rehfeldt (2007) addressed this limitation and subsequently demonstrated derived requesting skills in two adults with severe developmental disabilities and language deficits by contriving CEOs. Contrived CEOs were arranged by using the interrupted chain procedure (Hall & Sundberg, 1987) during chained tasks (where a larger sequence of responses is broken down) to create a state of deprivation for a mand. Rosales and Rehfeldt utilized the behavior chain of playing a CD with a CD player. This task can be analyzed into several steps (e.g., open CD holder, remove CD, open player, place CD inside, etc.); if an item needed to complete the chain (and hear the music play) was withheld, in this case the CD itself, it creates an EO for a mand. As with Rehfeldt and Root (2005), participants were probed for text manding and other relations, then taught to conditionally relate the dictated names of the items to the pictures (A-B training) and to printed text (A-C training) and subsequently probed for derived requesting with text and other relations. Both participants showed the emergence of derived requests/mands and some derived stimulus relations.

Although a growing body of derived stimulus relations research has been conducted with individuals with mild developmental disabilities or neurotypically developing children (Murphy & Barnes-Holmes, 2009, 2010; Murphy, Barnes-Holmes, & Barnes-Holmes, 2005), as well as with adults (Halvey & Rehfeldt, 2005; Rehfeldt & Root, 2005; Rosales & Rehfeldt, 2007), there is a dearth of research with children with limited verbal repertoires, such as children with ASD (McLay, Sutherland, Church, & Tyler-Merrick, 2013; O'Donnell & Saunders, 2003). Indeed, up to 25% of children with ASD are estimated to never fully acquire speech (Klinger, Dawson, & Renner, 2002) and many rely on an augmentative and alternative communication (AAC) device as their primary mode of communication (Mirenda & Iacono, 2009). In AAC systems, the use of symbols or images act as functional substitutes for existing speech (Murray & Goldbart, 2009; Nunes, 2008), and one of the most widely used systems is the PECS (Frost & Bondy, 2002). Studies show that basic communication skills are readily acquired using PECS and that levels of spontaneous speech and social-communicative behavior also increase (Charlop-Christy, Carpenter, Le, LeBlanc, & Kellet, 2002).

Recently, there has been an explosion of interest in "high-tech" speech generating devices (e.g., Kagohara et al., 2013; Still, Rehfeldt, Whelan, May, & Dymond, 2014), in which important single words, phrases or sentences are vocally produced by the device itself (Schepis, Reid, & Behrman, 1996). The potential implications of these devices for facilitating improved communications skills of children with ASD have grown enormously since the release of the Apple iPad® and the availability of thousands of dedicated applications for use with these and similar devices (Still et al., 2014). There are many advantages to these devices over other interventions systems such as PECS, including the increased size of the 'vocabulary store' (i.e., the number of pictures or symbols a device can hold), the decrease in size of the device (i.e., a PECS book is 25.5 cm × 23 cm, whereas the Apple iTouch™ is 12.3 cm × 5.9 cm), the reduced setup and maintenance time (e.g., extending vocabulary stores can be as simple as taking a photograph with the device itself or recording a person saying a new word, rather than, with PECS books, cutting and laminating of images, etc.). King et al. (2014) found that children with ASD can learn PECS-like requesting skills for preferred items using the Proloquo2Go™ application on the Apple iPad® and that vocal requesting increased relative to baseline. However, no studies to date have incorporated derived relational responding procedures with requesting skills training using high-tech tablet devices with children with ASD with limited verbal abilities. Moreover, it is important to evaluate procedures based on theoretical approaches that have the potential to reduce the time requirements of teaching programs (May & Dymond, 2014). As Knight, McKissick, and Saunders (2013) highlight, "each intervention has a cost, even if that cost is simply time" (p. 19). The objective of the present study was to develop and validate a high-tech intervention device to facilitate requesting in children with ASD.

In the present study, two experiments were conducted in which a CEO procedure was implemented with children with ASD who lacked a vocal repertoire. Using the RCP, children were first taught to mand for the needed (missing) items necessary to play with a toy by exchanging pictures of the items for the items themselves on a touch screen tablet computer. Participants then learned to conditionally relate the dictated names of the items to the corresponding pictures of the items (A-B) and to relate the dictated names to the corresponding printed words (A-C) using an adapted RCP implemented on the touchscreen tablet computer. Test probes, in the absence of reinforcement, were presented to ascertain whether or not participants would mand for the missing items using text rather than pictures (thus demonstrating derived requesting). Probes for spontaneous matching (B-C and C-B) were presented in both experiments while labeling (B-A and C-A) probes were also presented in Experiment 2. The rationale for including these derived relations probes (symmetry and equivalence) was to examine whether derived requesting would emerge in the absence of a prior test for derived relations. Previous laboratory research with typically developing adults has shown that a prior test for stimulus equivalence is not necessary for transfer or transformation of functions to occur (see Dymond & Rehfeldt, 2000, for a review), although relation-consistent test performance following predicted transfer performance indicates that the emergent outcomes involved the stimulus relations expected to be produced by the training phases. Experiment 1 of the present study sought to examine whether a prior test for derived stimulus relations was necessary to show derived requesting in children with ASD (see also, Rehfeldt & Root, 2005), while Experiment 2 probed for the emergence of the requisite derived relations throughout all phases. Importantly, Experiment 1 employed a pretest/posttest design and Experiment 2 employed a multiple probe across participants design.

The first aim of the study was to conduct formal expressive and receptive language assessments at the outset, in order to facilitate standardized classification of participants' language abilities. A secondary aim was to adapt the procedure used by Rosales and Rehfeldt (2007) in which the interrupted chain procedure (Hall & Sundberg, 1987) was implemented during chained tasks. We utilized a missing items procedure (Carroll & Hesse, 1987) to create conditions to mand for an item. This shortened the teaching sequence considerably (there was no teaching of a chained task), thus making the procedure more accessible to young children with severe disabilities and potentially allowing for the more rapid acquisition of manding. The final aim of the study was to contribute to the evidence base that high-tech devices can be used to demonstrate derived requesting in line with the proliferation of such devices used to augment speech in individuals with communication impairments (Common Sense & Rideout, 2011; Sennott & Bowker, 2009).

2. Method

2.1. Experiment 1

2.1.1. Participants and setting

Eight children, six males and two females, aged between 3 and 12 years old, with an independent diagnosis of autism spectrum disorder (DSM-IV-TR) were recruited via professional contacts. Participants' receptive and expressive language abilities were assessed using the *British Picture Vocabulary Scale-Third Edition* (*BPVS-III*; Dunn, Dunn, Styles, & Sewell, 2009) and the *Expressive Vocabulary Test-Second Edition* (*EVT-II*; Williams, 1997), and none were taking prescribed medication. Manding for P1 to P8 occurred via PECS or a combination of gestures and vocalizations. The Swansea University Department of Psychology Ethics Committee approved the study. Informed consent was obtained from parents or guardians prior to the study.

Sessions were either conducted in a small room either in a school building containing a table and chairs or in an empty room at the participant's home, furnished with sofas, a table and chairs.

2.1.2. Materials

Pre-teaching session materials consisted of a pen, the BPVS and EVT scoring sheets and test materials (a ring binder with printed pictures on each page). For preference assessments, materials included forced-choice data sheets and six toy options (a ball popper toy and ball, a car loop and car, a train and track, an etch-a-sketch and pen, a marble run and marble and a four-piece puzzle) and six edible options (based on the preferred food items recommended for each individual participant by their parent/teacher). Teaching session materials included a *Dell*™ *Latitude*™ touchscreen tablet computer and two preferred toys chosen by each participant. Preferred edibles were also present for use during teaching trials. All sessions were video recorded and data were recorded via data sheets and the automated program. Stimuli were designated as A1, B1, C1, and A2, B2, C2 (participants were not exposed to these labels). In all cases, the A stimuli were the dictated names of the items, the B stimuli were the corresponding pictures of the items, and the C stimuli were the corresponding printed words for the items.

2.1.3. Interobserver agreement

An independent observer scored 33% of all training sessions and 33% of all probe sessions. Agreement was calculated by dividing agreements by agreements plus disagreements and multiplying by 100%. The mean percentage of observer agreement was 100% for all sessions with P1, 99% (range 98–100%) for all sessions with P2, 97% (range 94–100%) for all sessions with P3, 99% (range 97–100%) for all sessions with P4, 100% for all sessions with P5, 100% for all sessions with P6, 98% (range 96–100%) for all sessions with P7, and 99% (range 98–100%) for all sessions with P8.

2.1.4. Experimental design

Experiment 1 employed a pretest/posttest (A-B) design. First, one set of pretest mand and stimulus relations probes (trials in the absence of feedback) were conducted. Following this, mand training was implemented as described below. Next, conditional discrimination training (name to picture; A-B; and name to text; A-C) was conducted and, finally, a full set of posttest mand and stimulus relations probes were conducted.

2.1.5. Procedure

2.1.5.1. Preference assessments. Six preferred edibles for each participant were identified via informal conversations with parents or teachers. A paired-stimulus preference assessment (Fisher et al., 1992) was then used to identify each participant's two most preferred items, which were then employed as reinforcers during the experimental training sessions (mand training and A-B and A-C training). An additional paired-stimulus preference assessment was conducted with each participant in order to determine the top two most preferred of the six researcher-chosen toys to be included in all trials in the study.

2.1.5.2. Manding probes. Manding probes evaluated the extent to which participants requested missing items needed to play with the toys by exchanging a picture of the item with the experimenter. Items that were laid out on the table prior to the session included one of the preferred toys (depending on which toy was about to be probed). Each trial was presented without the critical item needed to play with the toy (i.e., the ball for the ball popper, the car for the loop, the train for the track, the pen for the etch-a-sketch, the marble for the marble run and a central puzzle piece for the puzzle). To start, participants were told, "It's playtime!", and when participants responded (or if there was no response after 10 s) the experimenter moved the tablet computer to the next trial without giving the item needed to play with the toy. This occurred regardless of whether the response was correct or incorrect.

Intermittent praise (e.g., "nice trying", "good sitting", etc.) was provided for attending to task instructions on a variable ratio of three (VR3) schedule. Participants one to four received 12 trials per block, each consisting of three comparison stimuli (the top two preferred toys for that child; the third comparison was another toy chosen at random from the six-item preference assessment), and participants five to eight received eight trials in each block consisting of two comparisons (the top two preferred toys for that child).

2.1.5.3. Derived requesting probes. Derived requesting probes evaluated whether participants could request for missing items needed to play with the toys by exchanging the text corresponding to the item. Items were laid out on the table prior to the session in the same manner as the picture mand probes (see Section 2.1.5.2). Regardless of the response made by participants during trials in this phase, the experimenter moved the tablet onto the next trial without giving the item needed to play with the toy. This was to ensure that responses were not reinforced for correct text exchanges (which, as above, would increase the probability of future correct text-based mand exchanges). Participants one to four received 12 trials per block, and participants five to eight received eight trials in each derived requesting probe block.

2.1.5.4. Derived relations probes. Matching pictures to text (B-C relations) and text to pictures (C-B relations), and spoken word to text (A-C relations) and spoken word to pictures (A-B relations) were tested using the RCP (see Fig. 1) to see if other relations were present prior to discrimination training. Differing numbers of trials for derived relations probes and training blocks were administered across participants. Participants one to four had six trials for each stimulus relation (totaling 24 trials for A-B, A-C, C-B and B-C probes). Each trial included three comparison stimuli (one correct and two incorrect). Participants five to eight had eight trials for each additional relation (totaling 32 trials for A-B, A-C, C-B and B-C probes). Again, each trial included two comparison stimuli (one correct and one incorrect) and no additional stimuli.

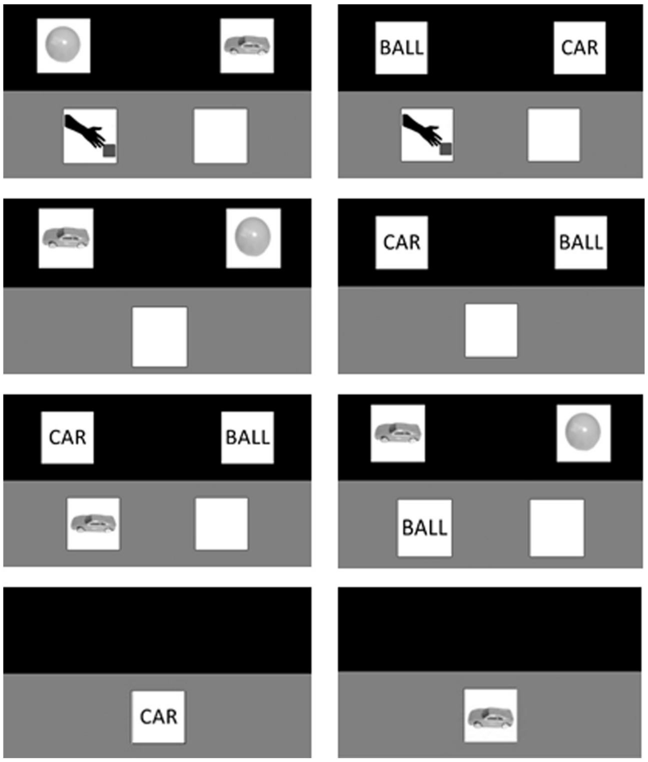

Fig. 1. Screenshots of all phases of the Relational Completion Procedure (RCP) employed in the present study. The top two panels illustrate mand training with pictures (left side) and testing with text (right side) matching trials. The panels below illustrate A-B (left side) and A-C (right side) matching trials in which an auditory sample stimulus is first presented and participants respond by dragging and drappping a comparison to the blank square. The panels below illustrate B-C (left side) and C-B (right side) matching trials in which a visual sample is first present and participants respond by dragging and drappping a comparison to the blank square. The lower two panels illustrate derived tacting probes with text (left side) and pictures (right side).

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For matching text to pictures (C-B relations) participants were presented with two written words on the tablet (see Fig. 1). A picture sample was displayed underneath the two text words, next to an empty box and participants were instructed by a vocal sample delivered by the tablet computer to "match". A correct response was defined as dragging and dropping the text of the item that corresponded to the picture sample into the blank box (see Fig. 1).

During matching of pictures to text (B-C relations) trials, participants were presented with two pictures on the tablet. A written text sample was displayed underneath the two pictures, next to an empty box and participants were instructed by a vocal sample delivered by the tablet computer to "match". A correct response was defined as before.

For both matching (B-C and C-B) probes, if after 10 s the participants did nothing or did something with the tablet other than correctly match, this was scored as an incorrect response, no comment was made and a new trial was begun. Positions of the comparison stimuli on the tablet computer varied randomly across trials.

In the conditional discrimination (A-B) probes, participants were presented with two pictures at the top of the screen and a single blank box underneath (Fig. 1). The tablet computer then instructed participants to "show me [item]" (e.g., "show me car"). A correct response was defined as dragging and dropping the picture of the item that corresponded to the spoken word into the blank box (so, in the above example, dragging and dropping the picture of the car). In order to allow for accurate probing of auditory matching (rather than auditory memory; for discussion see Green, 2001), the auditory comparison stimulus was repeated every 3 s until the trial ended.

For both conditional discrimination probes (A-B and A-C), if after 10 s the participants did nothing or did something with the tablet other than correctly select the item that corresponded to the spoken word, this was scored as incorrect, no comment was made and a new trial began. Positions of the comparison stimuli on the tablet were varied randomly across trials.

2.1.5.5. Mand training. In the mand training phase, participants were taught to ask for the missing part of the toy needed to play with it using the corresponding picture on the tablet (e.g., the train needed to play with the train track). Part of a toy was placed on the table next to the tablet followed by the "I want" picture, which was presented on the bottom of the screen with two photos above it (one of which was of the missing toy). Prompts were given for dragging and dropping the correct picture for the corresponding toy item into the space next to the "I want" picture. Missing toys in the mand training phase were given to participants after a correct mand. Training was conducted in 12- or 8-trial blocks (for participants one to four and five to eight, respectively). Each trial was an opportunity to mand for one missing part of a toy. To start each task, participants were told, "it's playtime", as in the probe phase. When an incorrect picture selection occurred, the experimenter moved to the next trial. Mastery criterion was 75% correct independent manding for one block. Verbal praise, the item being manded for, and a preferred edible were provided in small quantities for correct responses (error-correction was not employed). Differential reinforcement and prompt fading were used to increase independent correct responding. That is, initially small quantities of edible reinforcers were provided for responses that were fully physically prompted and then when less prompts were needed or independent responses occurred, larger edibles were provided. Prompt fading was implemented by beginning with full prompts then reducing the prompt levels (e.g., partial physical prompt, gestural prompt, etc.) until independent responding occurred.

2.1.5.6. Conditional discrimination training (A-B and A-C relations). In the conditional discrimination phases, participants were taught to conditionally relate the dictated names of items to their corresponding pictures (A-B training) and corresponding text (A-C training). Participants were first taught A-B relations (e.g., to select the picture of the car when the tablet computer emitted the auditory sample, "show me car"). Criterion performance was achieved when participants independently selected the correct picture when the instruction "show me [item]" was given with 75–100% accuracy over one block. Once criterion performance had been achieved with the pictures (A-B relations), participants were taught to select the written text of the words when the instruction "show me [item]" was delivered (A-C relations). After mastery of A-C relations, mixed trials of selecting both picture and text trials were conducted (A-B and A-C relations). Mastery criterion to move to the post-test probes phase was achieved when participants were independently selecting the correct picture or word when the instruction "show me [item]" was given with 75–100% over two mixed blocks of 16 trials. In the first block of mixed trials, every correct response was reinforced, while in the second block of trials every second trial was consequated (participants were not forewarned about the fading of differential reinforcement). Verbal praise and a preferred item (as determined by the preference assessment) were delivered in small quantities for correct responses. Differential reinforcement and prompt fading were used to increase independent correct responding. When an incorrect response occurred, no feedback was given and the response was not reinforced.

3. Results and discussion

Participants' EVT and BPVS scores are displayed in Table 1. All participants scored lower age equivalents than their chronologic age, suggesting impairment in expressive and receptive language abilities. Table 2 shows trials to criterion and percent correct during the conditional discrimination training phases (Phases 2–4) and Fig. 2 shows A-B (dictated names to pictures) and A-C (dictated names to text) probes performance during pretest and posttest. All participants except P1 and P5 responded at between 0% and 50% accuracy levels, suggesting that the A-B and A-C auditory to picture and text relations were absent from their repertoire prior to training of the requisite relations. Both P1 and P5's pretest data indicate a prior

Table 1
Participants' chronological ages, *Expressive Vocabulary Test* (EVT) and *British Picture Vocabulary Scale* (BPVS) scores, presented as percentiles and age equivalent scores, from Experiments 1 and 2.

Experiment	Participant	Age	EVT		BPVS	
			Percentile	Age equivalent	Percentile	Age equivalent
1	P1	5y8m	<0.1	<2y	<2	<3y9m
	P2	8y4m	0.2	4y7m	<2	<3y9m
	P3	8y5m	<0.1	2y1m	<2	<3y9m
	P4	9y6m	0.5	4y11m	<2	<3y9m
	P5	4y5m	6	2y11m	4	<3y9m
	P6	3y9m	2	<2y	<2	<3y9m
	P7	5y7m	<0.1	<2y	<2	<3y9m
	P8	8y5m	1	4y3m	<2	4y1m
2	P1	4y4m	23	3y8m	20	<3y9m
	P2	7y2m	1	3y9m	<2	<3y9m
	P3	8y9m	<0.1	3y1m	<2	<3y9m

level of competency in the to-be-targeted A-B and A-C relations, despite their low scores on the formal language assessments.

The results from the derived requesting ('independent') probes, pretest and posttest, are presented in Fig. 3. During the pretest probes, participants' correct independent text mand exchanges ranged from 0% to 38%. Only three of the eight participants produced any independent mands at all. Later, during the posttest probes, all participants' scores increased to between 67% and 88% of independent derived (text) mands. Errors during the derived manding posttest probes were typically the same for all participants and usually occurred on trials for the same item. Participants tended to request playing with a toy other than one presented to them by reaching for it or using words and gestures before manding for the item using the tablet (resulting in an 'incorrect' mand).

The results of the pre- and posttest C-B and B-C derived relations tests are presented in Fig. 4. At pretest, the probe scores ranged from 0% to 59%, while during the posttest, probe performance ranged between 81% and 100% accuracy.

In summary, the findings of Experiment 1 clearly demonstrate an increase in derived relations consisting of individualized sets of spoken words, text and images and in derived manding responses using text exchange in eight children with ASD with limited verbal abilities. The increase in derived manding responses was observed consistently in all children regardless of their formal language scores and, as the pretest/posttest differences revealed, required the formation of derived relations involving each child's picture and text stimuli. These findings were obtained with a touchscreen tablet computer as the medium of exchange and, as such, add to the existing literature on derived requesting/manding in children and adults with ASD and other developmental disorders (Halvey & Rehfeldt, 2005; Murphy & Barnes-Holmes, 2009, 2010; Murphy et al., 2005; Rehfeldt & Root, 2005; Rosales & Rehfeldt, 2007).

Table 2
Trials to criterion and percent correct for Phase 2 (A-B), Phase 3 (A-C) and Phase 4 (mixed A-B and A-C) conditional discrimination training for participants one to eight (Experiment 1) and participants nine to eleven (Experiment 2).

Participant	Phase 2: trials to criterion	Phase 2: percent correct (A-B)	Phase 3: trials to criterion	Phase 2: percent correct (A-C)	Phase 4: trials to criterion	Phase 4: percent correct (A-B and A-C)
P1	6	100%	6	100%	24	100%
P2	240	92%	36	100%	12	100%
P3	54	83%	36	100%	12	83%
P4	30	83%	24	83%	36	94%
P5	16	100%	8	88%	16	88%
					16[a]	94%
P6	16	88%	24	100%	16	100%
					16[a]	100%
P7	32	100%	168	88%	64	88%
					16[a]	81%
P8	24	88%	304	100%	16	94%
					16[a]	100%
P9	16	100%	120	88%	16	100%
					16[a]	100%
P10	8	88%	24	88%	16	88%
					16[a]	88%
P11	8	100%	32	100%	16	100%
					32[a]	88%

[a] A block of trials with faded reinforcement in Phase 4.

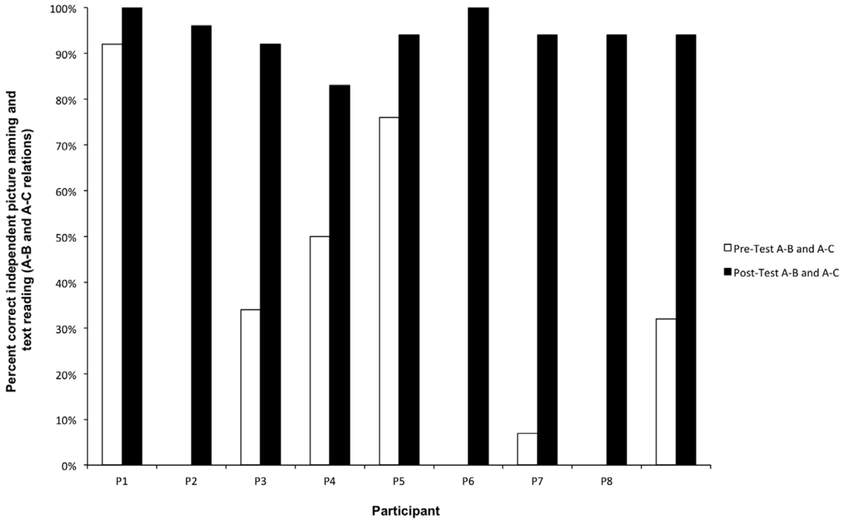

Fig. 2. Percentage of correct independent dictated name to picture (A-B) and dictated name to text (A-C) relations at pretest and posttest in Experiment 1.

There are potential limitations to the pretest/posttest design used in the present study and many of the previous studies on derived manding. For instance, the design does not remove all threats to internal validity because it may be subject to test/re-test sensitivity. Within single case research (Kennedy, 2005), there are a number of alternatives to pretest/posttest designs that may overcome this limitation. In particular, the multiple probe design may be suitable in this regard (Barlow, Nock, & Hersen, 2009; Horner & Baer, 1978; Kazdin, 1982); indeed, several previous studies have used this design in analysis of derived manding (e.g., Rosales & Rehfeldt, 2007). In Experiment 2, we employed a multiple probe design with different participants to further validate the present protocol.

3.1. Experiment 2

3.1.1. Participants and setting

Three children, two males and one female, aged between 4 and 12 years old, with an independent diagnosis of ASD (DSM-IV-TR) were recruited via professional contacts. Participants' receptive and expressive language abilities were assessed as described earlier and none were taking prescribed medication. P9 and P10 used a combination of eye gaze, gestures and words to mand for items. P11 led adults by the hand to indicate the things he wanted in addition to using pictures or some

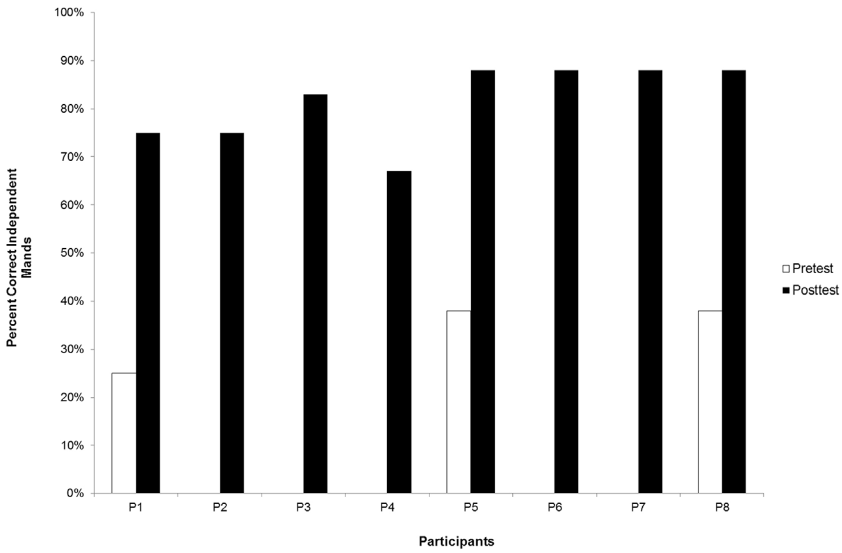

Fig. 3. Proportion of correct independent mands during pretest and posttest in Experiment 1.

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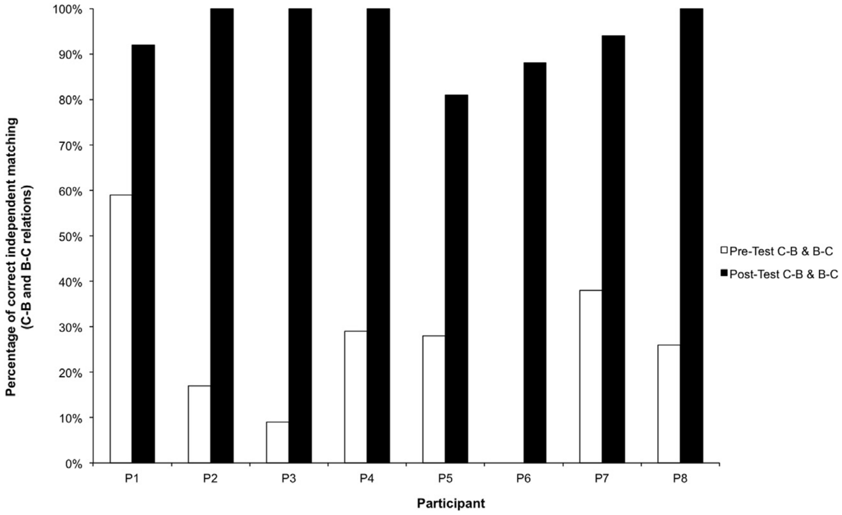

Fig. 4. Proportion of correct independent matching relations (B-C and C-B) during pretest and posttest in Experiment 1.

spoken words. The Swansea University Department of Psychology Ethics Committee approved the study and informed consent was obtained from participants' parents or legal guardians prior to the beginning of the study. Participants' EVT and BPVS scores are displayed in Table 1.

Sessions were conducted in a small room in a school building containing a table and two chairs.

3.1.2. Materials

Materials as included in Experiment 1.

3.1.3. Interobserver agreement

Interobserver agreement was scored for 33% of all training sessions and 33% of all probe sessions and calculated as in Experiment 1. The mean percentage of observer agreement was 100% across all sessions for all participants.

3.1.4. Experimental design

A multiple probe, multiple baseline design (Barlow et al., 2009; Horner & Baer, 1978; Kazdin, 1982) across three participants was used (Rehfeldt & Root, 2005; Rosales & Rehfeldt, 2007). First, derived mand and stimulus relations probes were conducted: three for P9, six for P10, and 11 for P11. Following this, picture manding and another full set of probes were conducted. Then, conditional discrimination (name to picture; A-B) training and another full set of probes were conducted. Finally, name to text training (A-C) and three full sets of probes were conducted.

Once visually stable baseline pretest mand and stimulus relations probes were established for a minimum of three sessions, two participants continued to receive probe trials while one was moved into the picture mand training phase. When this participant had attained criterion performance (88–100%) in the manding with pictures training, then another set of probes were administered. Following the set of probes, conditional discrimination training (A-B and a set of probes then A-C) was introduced. Finally, three posttest mand and stimulus relations probes were conducted. After the initial participant had completed the posttest probe sets, the second participant received the picture mand and conditional discrimination training phases while the third participant continued to receive pretest probes. After the posttest probe sets were complete with the second participant, the third participant received the picture manding and conditional discrimination training phases. Finally, the third participant completed posttest probes.

3.2. Procedure

3.2.1. Preference assessments

Preference assessments were conducted as in Experiment 1.

3.2.2. Manding probes

Manding probes were conducted as in Experiment 1 with the only exception being the number of trials included per block. Participants in Experiment 2 all had eight trials in each probe or training block.

3.2.3. Derived requesting/manding probes

Derived manding probes were conducted as in Experiment 1.

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3.2.4. Derived relations probes

Derived relations probes were conducted as in Experiment 1 with the exception of the number of trials per block, which totaled eight trials per relation (totaling 32 trials for A-B, A-C, C-B and B-C probes).

3.2.5. Mand training phase

Mand training trials were conducted as in Experiment 1 with the exception of the number of trials per block (eight).

3.2.6. Conditional discrimination training phases (A-C and A-B relations)

Conditional discrimination training trials were conducted as in Experiment 1.

3.2.7. Derived relations probes (B-A and C-A relations)

An important difference from Experiment 1 was the inclusion of tacting pictures (B-A relations) and tacting (or reading) of written text (C-A relations) in all probe trial blocks. Participants were shown one photo of either preferred toy on screen and asked: "what is it?" Correct responses were defined as saying the name of the preferred item when shown its picture (B-A relations) or text (C-A relations). If participants did not vocalize or vocalized the incorrect name after 10 s, then this was scored as an incorrect trial.

4. Results and discussion

The emergence of derived manding and derived stimulus relations, including tacting (B-A), reading text (C-A), picture-text matching (B-C), text-picture matching (C-B), were inferred if a participant performed correctly on 88% (seven of eight) or higher of the test trials for each respective skill.

4.1. Mands and derived stimulus relations probes

4.1.1. Pretest probes

For all derived mand probes, P9 scored 0%, P10 scored between 38% and 63%, and P11 scored between 0% and 50%, which is indicative of chance levels of responding (Fig. 5). None of the participants were able to mand for the items using the text corresponding to the item that was placed in front of them prior to A-C training.

4.1.2. Derived stimulus relations probes

P9 scored 0% on the picture-naming (B-A relations; Fig. 6) and text-reading (C-A relations; Fig. 7) probes. P10 scored between 25% and 50% on the picture-naming (B-A relations; Fig. 6) and text-reading (C-A relations; Fig. 7) probes. P11 scored between 38% and 100% on picture-naming (B-A relations; Fig. 6) probes and between 0% and 25% on text-reading (C-A relations; Fig. 7) probes. P11's scores indicate that B-A stimulus relations were in his repertoire prior to A-B and A-C conditional discrimination training, while the scores for all other relations resembled chance level responding.

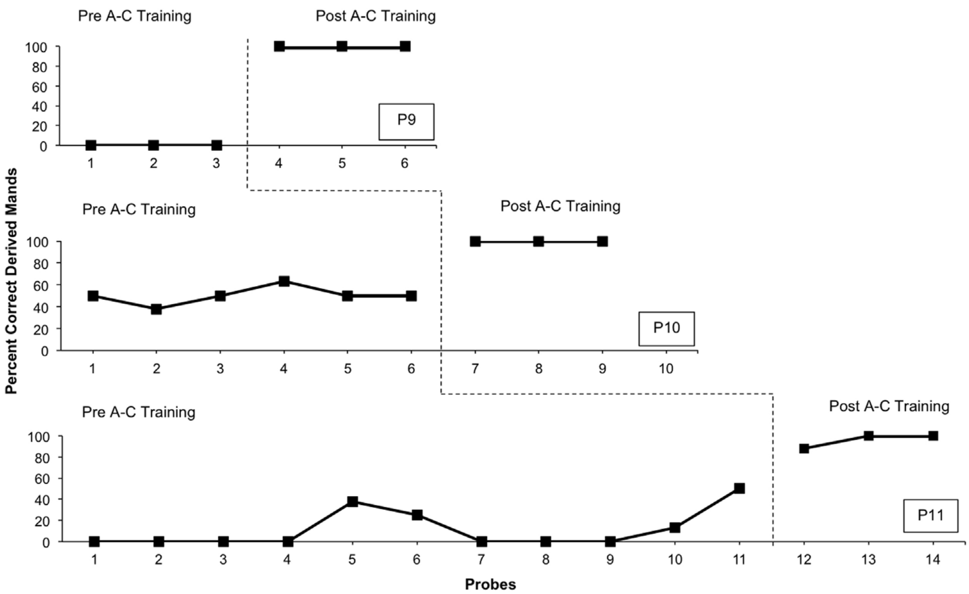

Fig. 5. Proportion of correct independent mands per block of eight probe trials before and after A-C training in Experiment 2.

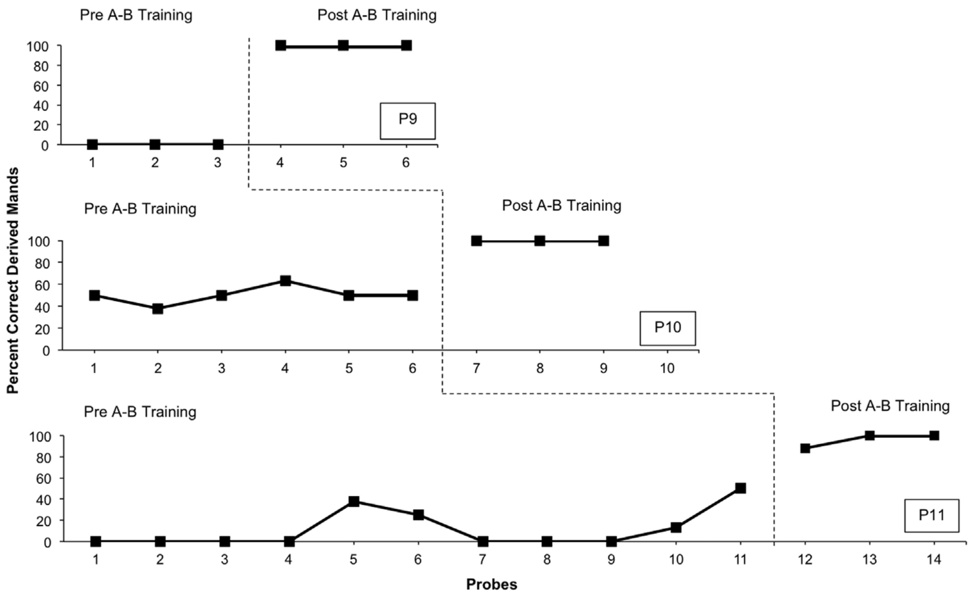

Fig. 6. Proportion of correct independent tacts (picture-naming) relations (B-A) per block of eight probe trials before and after A-B training in Experiment 2.

Fig. 8 shows A-B, A-C, B-C and C-B probe trial performance pre- and post A-C training. In the pretest probes for picture-to-text matching (B-C relations) and text-to-picture matching (C-B relations), P9 scored between 16% and 50%, P10 scored between 41% and 66%, and P11 scored between 22% and 47% (Fig. 8).

4.2. Mand training phase

P9 required 32 trials (100%), P10 required 32 trials (88%), and P11 required 40 trials to meet criterion (100%) during this phase.

4.3. Conditional discrimination phase

Table 2 shows trials to criterion and percent correct during the conditional discrimination training phases (Phases 2–4). P9 required 16 trials (100%), P10 8 trials (88%), and P11 demonstrated a criterion level of correct independent responding

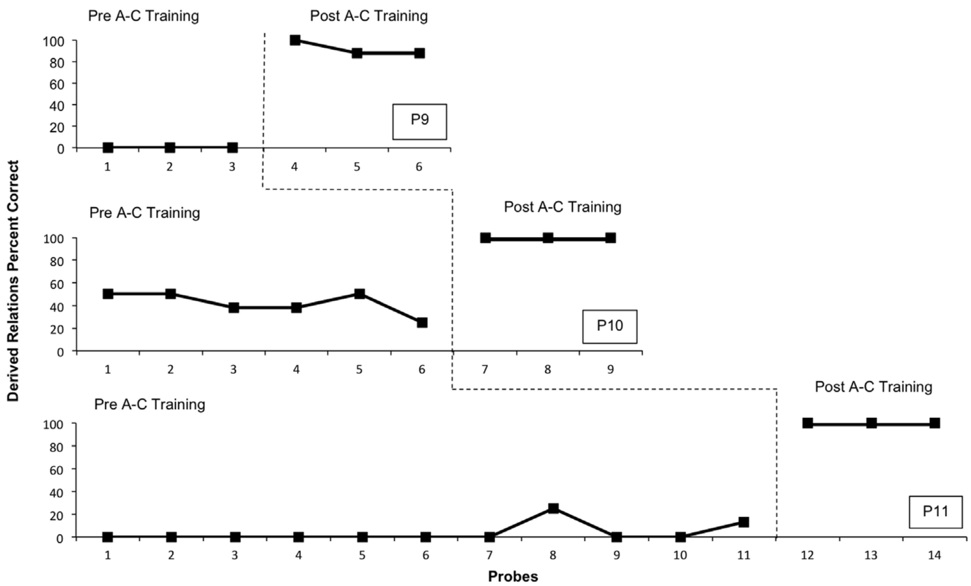

Fig. 7. Proportion of correct independent text-reading relations (C-A) per block of eight probe trials before and after A-C training in Experiment 2.

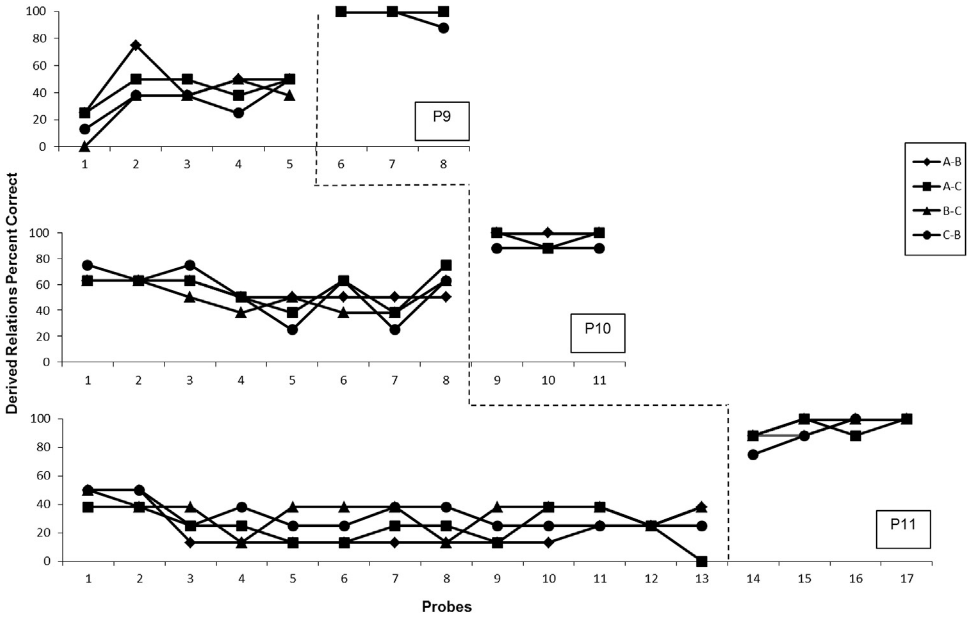

Fig. 8. Proportion of correct independent picture-naming (A-B) and text-reading (A-C) conditional relations and picture to text matching (B-C) and text to picture matching (C-B) derived relations before and after A-C training in Experiment 2.

with A-B relations in 8 trials (100%). P9 demonstrated 88% correct independent responding with A-C relations after 120 trials, P10 demonstrated criterion responding in 24 trials (88%), and P11 in 32 trials (100%). In the mixed A-B and A-C trials, P9 achieved criterion responding (100%) in the minimum number of trials for both blocks of trials. P10 also achieved criterion responding (88%) in the minimum number of trials for each schedule of reinforcement. P11 achieved criterion responding (100%) in the minimum number of trials and then required two blocks (32 trials) when every second correct response was reinforced (88%).

4.4. Derived manding and derived relations probes

P9 and P10 scored 100% correct text requesting (derived manding) on all post A-C training probes. P11 scored 0% correct text requesting on the first post A-C block. Then, after mixed A-C and A-B trials, he met criterion levels of responding on his final three posttest probes (≥88%). Post A-C training derived relations probes (A-B, A-C, C-B, B-C) all ranged between 88% and 100% for all three participants in Experiment 2.

5. General discussion

The findings of the present study provide supportive evidence for the use of a CEO procedure implemented with the RCP on a touchscreen tablet computer for children with ASD who lacked a vocal repertoire. Following formal expressive and receptive language assessments and preference assessments, children were taught to mand for a missing item needed to play with a preferred toy by picture exchange. Participants then learned to conditionally relate the dictated names of the items to the corresponding pictures of the items (A-B) and to relate the dictated names to the corresponding printed words (A-C). Test probes, in the absence of reinforcement, were presented to determine whether or not participants would mand for the missing items using text rather than pictures (and thus demonstrate derived manding). Probes for spontaneous matching (B-C and C-B) and labeling (B-A and C-A), based on derived stimulus relations formed among the relations, were also presented. Across two experiments, one using a pretest/posttest design and the other a multiple probe across participants design, all but one of the participants (P4) demonstrated derived manding and the requisite derived relations. Taken together, these findings add to the growing evidence base of applied relational frame theory studies synthesizing verbal operants with derived relational responding (Halvey & Rehfeldt, 2005; May, Hawkins, & Dymond, 2013; Murphy & Barnes-Holmes, 2010; Rehfeldt & Root, 2005; Rosales & Rehfeldt, 2007).

There are several advantages to the present protocol to facilitating derived manding. First, administering preference assessments at the outset meant that participants were manding for objectively defined, preferred items. Second, utilizing the missing items procedure with each participant's unique set of preferred items allowed us to conduct repeated probes during acquisition and testing, which helped limit any satiation effects. Third, to the best of our knowledge, this was the first study to employ a touchscreen tablet computer in a manner resembling an AAC device as an integral part of the procedures to facilitate derived manding. Research investigating the impact of tablet devices such as the iPad (e.g., King et al., 2014) is small but growing (Still et al., 2014) and the present study clearly shows that such devices afford excellent opportunities to foster independent communication skills in populations with limited verbal abilities. Fourth, the manding and discrimination training and testing phases were implemented on the same platform – the RCP. This permitted a continuous, context-specific presentation of tasks designed to closely approximate a range of functional requesting and relational learning repertoires in children. The successful yields on tests for derived relations, and the incorporation of individualized stimulus sets for the different participants, adds to the growing empirical literature on applications of the RCP (e.g., Walsh et al., 2014). Our findings suggest that the emergence of auditory-visual derived stimulus relations is possible with young children with severe developmental disabilities and significant language impairments. Finally, despite the fact that all participants showed evidence of language impairment in the formal assessments, all went on to demonstrate derived manding and the requisite derived relations. This highlights that caution should be exercised when extrapolating from formal language assessments to the likelihood of developing independent functional communication skills. It is noteworthy that minimal research has been conducted on the purported functional relationship between the generative skills produced by outcomes of tests for derived relations and formal language assessment scores (O'Donnell & Saunders, 2003).

Although the interrupted chain procedure may be more effective at evoking manding than the missing items procedure, the decision about which procedure to employ often depends on factors such as time availability, the need to teach as many mands as possible, or the presence of pre-requisite skills which might enable the teacher to target the acquisition of other chained tasks. One procedure, the missing items, is simpler to acquire and faster to administer, while the other teaches additional skills (chained tasks) that may be more complex for young and/or severely developmentally delayed children. However, our use of the missing items procedure suggests that it has broad applicability to educational and clinical interventions aimed at promoting independent communication skills. Further research evaluating the two procedures in the context of derived manding appears warranted.

All participants demonstrated proficiency in manding for items using pictures on the tablet computer and our results support emerging empirical data demonstrating the efficacy of new technology AAC systems with children with developmental disabilities (Kagohara et al., 2013; Still et al., 2014). The results also benefited from some of the advantages of the automated procedure for facilitating derived relational responding in individuals with language delays (such as reduced likelihood of experimenter cueing and more reliable and accurate data collection). Indeed, it was evident that a history of reinforced conditional discrimination learning readily leads to the emergence of derived manding in young children with severe developmental disabilities and language impairments and that the missing items procedure (Carr & Kologinsky, 1983) was effective for all but one of the participants.

5.1. Limitations

Potential limitations of the study include the following. First, in Experiment 1, with P4, the 67% score on the posttest manding trials could potentially have been due to the shift in preference for one item since he demonstrated the other derived relations without issue (C-B and B-C relations probe scores were 100%). During those final posttest mand probe sessions, it was found that P4 asked for one item more often than another and had, in effect, lost interest in playing with the other item. Preference shifts such as this could have been measured by adding additional preference assessments into the procedure or simply by repeating the preference assessment. However, the missing items procedure is not capable of addressing this issue because the CEO relies on the preferences being sustained throughout the task. Also, repeating the assessment was not practical because it would have necessitated retraining (and testing) of the stimulus relations required for derived effects to be shown. These issues notwithstanding, future research should explore ways of ensuring that preferences are intact across studies involving multiple sessions such as this without the need to re-run the preference assessments while ensuring that requisite EO conditions are present during mand training. Second, some of the procedures required the use of edible reinforcers and for mand exchanges to be consequated by an experimenter (thus tempering some of the potential benefits that could be provided by a fully automated procedure). Future research should investigate further automating the delivery of reinforcement and incorporating a derived manding procedure. Third, due to the multiple training and testing sessions involved, we only accepted study participants with low rates of challenging behavior who possessed the requisite levels of manual dexterity needed to operate the touchscreen interface. The device and protocol are readily capable of being adapted to suit the needs of users who might require greater assistance across the different phases of the intervention. Further research should seek to examine these issues by adapting the task for use with individuals with physical disabilities. Fourth, not all toys or items identified by teachers and parents could be included in the preference assessments as there was a need to find preferred items with a 'missing part'. This may have resulted in a partial assessment of items that could have been used to evoke manding. Whether or not manding evoked by preferred and non-preferred items differ in the missing items procedure warrants further empirical attention. Finally, a potential criticism of the current procedures is that the communicative episode was mediated by the tablet computer and did not occur in a representative social context, with no eye contact or social exchange with a caregiver required. At face value, while this criticism may also be applied to any AAC intervention, especially one that focuses only on a limited vocabulary or request set size, it is important to note that the present approach utilized objective preference assessments to determine specific preferred items for each child. Thus, the exchange mimicked in the present protocol involved actual preferred items and the use of a touchscreen tablet PC offers unlimited opportunities to expand the range of social and communicative skills of children with

ASD. Further research should, however, extend the use of the present approach to multiple social contexts and communicative exchanges and to larger vocabulary size.

6. Conclusions

Although teaching strategies play a crucial role in the efficacy of an intervention (Frost & Bondy, 2002), within the context of AAC devices, the utility of the technology itself cannot be overlooked. The many benefits these devices confer (e.g., simultaneously increasing the vocabulary store and decreasing the size of the device, etc.) set high-tech AAC devices apart from their predecessors and warrant further exploration in the context of generative language. Potential benefits of high-tech AAC devices that require additional research include the determination as to whether portable electronic devices also have the potential to facilitate child-led expansion of vocabulary set size by allowing the user to incorporate photos. Additionally, investigation into whether high-tech devices provide a more socially acceptable mode of communication for adolescents and adults than exchanging PECS pictures is warranted (Rehfeldt & Root, 2005). It is, after all, the objective of such devices that they be used in a social context.

As outlined in Section 1, the ability to establish an extensive derived mand repertoire has wide reaching effects. For example, there may be a concurrent reduction in challenging behavior due to increased manding ability. If a child has multiple ways of asking for something he or she wants/needs, then appropriate alternatives (rather than challenging behavior) may be attempted to gain access to reinforcement if one way is mislaid (e.g., with one PECS picture being misplaced). Future research should consider examining expanding the 'vocabulary size' of this population while also measuring challenging behavior. A substantial derived mand repertoire may also have implications for increasing the behavioral flexibility that individuals with ASD frequently have difficulties with. It would also be beneficial to study the long-term maintenance and generalization of the derived requesting skills (Rosales & Rehfeldt, 2007).

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