A Comparison of Prompt Delays with Trial-and-Error Instruction in Conditional Discrimination Training

Sean J. O'Neill¹ · Claire McDowell¹ · Julian C. Leslie¹

Published online: 23 May 2018
© Association for Behavior Analysis International 2018

Abstract

Many prompting procedures exist for teaching skills to individuals with autism spectrum disorder and intellectual disability; however, direct comparisons between variations of prompt delay are rarely made. Here, we compared three variations of prompt delay (2-s or 5-s constant delay and 5-s progressive delay) alongside trial-and-error instruction. Four learners were taught a conditional discrimination task using a match-to-sample arrangement. Performances were compared using effectiveness and efficiency measures in an adapted alternating treatments design. A procedural modification, in the form of differential reinforcement, was applied to the prompt delay procedure for two of the four participants. With or without this procedural modification, results suggest progressive prompt delay may be effective and the most efficient in reducing learner errors during instruction.

Keywords ASD · Conditional discrimination · Prompt delay · Time delay · Differential reinforcement

Introduction

Instructional interventions in applied behavior analysis (ABA) are designed to enable learners to better function, and thrive, across environments. Once a behavioral skill deficit has been identified, and when it is clear this deficit hinders an individual's level of independence or life-quality, instruction-based interventions are used. These are typically used to build an individual's skill repertoire, thus allowing them to more fully engage and function educationally or at home. It is recommended that all intervention components be evidence-based and preferably supported by experimental studies showing them to be efficacious in the population of interest (Odom et al. 2010; Wong et al. 2015). Conditional discrimination training is extensively used to achieve learning objectives for individuals with autism spectrum disorder (ASD) and/or

intellectual disability (ID). It consists of four elements: a conditional stimulus, an antecedent stimulus, a response, and a consequence. An efficient way of teaching conditional discriminations is through the use of match-to-sample (MTS), which is commonly used in conjunction with response prompting and prompt-fading strategies (Green 2001).

Many prompt and prompt-fading procedures are available to clinicians to teach a variety of skills to learners with ASD/ID. These have been discussed elsewhere more extensively (Cooper et al. 2007; Fentress and Lerman 2012; Green 2001; Schuster et al. 1988; Schuster et al. 1992; Soluaga et al. 2008; Walker 2008; Wolery and Gast 1984), and both prompting and time delay are categorized as evidence-based practices by Wong et al. (2015) in their systematic review. It is prompt delay (PD), and permutations of that procedure, that will be the main focus here (Snell 1982; Snell and Gast 1981; Touchette 1971; Touchette and Howard 1984). This antecedent-based instructional procedure is referred to as time delay or delayed prompting in much of the research literature (Bennett et al. 1986; Demchak 1990; Handen and Zane 1987; Touchette and Howard 1984; Walker 2008; Wolery et al. 1992). The term PD is used here as it more closely aligns conceptually with the procedure: as it is the prompt, rather than time, that is delayed (Coleman-Martin and Heller 2004; Heal et al. 2009; Karsten and Carr 2009; Reichow and Wolery 2011; Vladescu and Kodak 2010).

✉ Julian C. Leslie
jc.leslie@ulster.ac.uk

Sean J. O'Neill
ONeill-S22@email.ulster.ac.uk

Claire McDowell
ce.mcdowell@ulster.ac.uk

¹ School of Psychology, Ulster University, Cromore Road, Coleraine, Northern Ireland BT521SA, UK

In the context of a MTS conditional discrimination task, initial PD trials begin by presenting a sample stimulus followed by comparison stimuli. Following this presentation, the instructor may immediately provide a gestural prompt to the target stimulus (S+). This zero-second delay or simultaneous prompting reduces the probability of the learner emitting an incorrect response. Subsequently, the prompt is delayed by an interval of time; this allows for an independent correct response to occur. Two variations of PD have been developed: progressive prompt delay (PPD) and constant prompt delay (CPD). After initial simultaneous prompting, the procedures differ. In a PPD procedure, the delivery of a prompt is subsequently delayed by small intervals of time that increase incrementally (e.g., 1 s, then 2 s, and so on up to a maximum or ceiling value) between instructional sessions. These incremental increases in delay value are typically contingent upon the learner's performance. Alternatively, the CPD procedure delays a prompt by the same fixed interval (e.g., 2 s) until a mastery criterion is achieved. Once mastery is achieved with either type of procedure, prompts are removed altogether once independent responses emerge. These PD procedures are associated with varying levels of errors during novel skill acquisition, but a major objective of these procedures is to reduce the number of learner errors (Handen and Zane 1987; Walker 2008; Wolery et al. 1992). Reduced error, or error-free, discrimination learning has previously been demonstrated with non-human subjects (Terrace 1963a, b) and in participants with ID (Touchette 1968, 1971). Results from those studies suggest that learning without errors is not only possible but may also be beneficial to participants by increasing the number of items learned, increasing contact with reinforcing contingencies, and in avoiding the development of error-prone repertoires (Schilmoeller et al. 1979).

Although the efficacy of PD is reported in several reviews (Demchak 1990; Handen and Zane 1987; Walker 2008; Wolery et al. 1992), and is supported as an evidence-based procedure (National Autism Center 2009; Wong et al. 2015), reviews tend to group PPD and CPD together and make recommendations for these procedures as a whole. This is true of the Wong et al. review and is presumably due to a scarcity of published work comparing the two variations (Ault et al. 1988).

In an attempt to identify the most effective and efficient prompt and prompt-fading procedure, Libby et al. (2008) directly compared three procedures: most to least (MTL), least to most (LTM), and MTL with a delay (MTLD). In the first experiment, MTL and LTM procedures were compared. All participants learned to build play structures with MTL, which was associated with fewer errors than LTM, but three participants learned more quickly with LTM. This finding suggests that MTL may prevent errors but it sometimes slows learning. A second experiment compared LTM to MTL without and with a delay (MTLD). MTLD provided an opportunity for

the learner to independently initiate responding but still minimized the likelihood of errors. Results showed that acquisition for the three participants was nearly as rapid in MTLD as LTM, but MTLD produced fewer errors than LTM, with MTL producing the slowest acquisition. These nuanced outcomes were only clear when instructional strategies were directly compared on measures of effectiveness and efficiency.

Effectiveness and efficiency measures have routinely been used to compare, evaluate, and differentiate instructional procedures (Alig-Cybriwsky et al. 1990; Carroll et al. 2015; Godby et al. 1987; Libby et al. 2008; Snell 1982; Walker 2008; Wolery et al. 1992; Wolery et al. 1993). Effectiveness refers to the reliability of a procedure to result in mastery, whereas efficiency measures may consist of a number of variables that quantify the amount of training required. These include number of training trials, sessions, and errors to criterion (Gast 2009). To date, only one study has directly compared two variations of PD: Ault et al. (1988) compared an 8-s PPD procedure with a 5-s CPD on performance with three learners with moderate ID when learning a community sign-reading task. Both procedural variations were effective with the 5-s CPD procedure being marginally more efficient than the PPD procedure. Results from this study did not conclusively favor one procedure over the other, with replication of a similar comparison recommended. Furthermore, no studies have directly compared these procedures with ASD learners using a MTS teaching arrangement, nor have more than two instructional conditions been compared simultaneously.

Other more traditional methods of instruction include trial and error (T&E). This method of discrimination learning is widely used in special education and elsewhere. T&E involves demonstrating a correct response to a learner at the outset, and subsequently providing little assistance; other than that provided contingent on an incorrect or correct learner response. Typically, it involves the availability of two or more stimuli. Selection of one stimulus results in reinforcement, whereas selection of another stimulus produces no reinforcement and is counted as an error. The reinforcement contingencies used in T&E learning are clear and contrasting, but learners with an ASD/ID may produce many errors (Schilmoeller et al. 1979). This may be problematic as tasks that occasion errors have previously been associated with challenging or disruptive behaviors in this population (Heckaman et al. 1998; Weeks and Gaylord-Ross 1981). In addition, some studies have shown T&E learning to be ineffective during skill acquisition in human and non-human subjects and may hinder future learning (Saunders and Spradlin 1990; Schilmoeller et al. 1979; Terrace 1963a; Touchette 1968). T&E instruction has not been systematically compared with PD in learners with ASD/ID, and therefore the relative efficacy of each remains untested.

The present investigation addressed a number of the issues raised here. It compared three variations of the PD procedure

(5-s PPD, 5-s CPD, 2-s CPD) alongside T&E instruction, to teach a receptive conditional discrimination task using an adapted alternating treatments design (AATD). The aims of the present investigation were threefold: (1) to determine which of these procedures was effective, (2) to identify which procedure was associated with the least number of training trials and errors to criterion, and (3) to provide clinicians with some guidance as to how to devise the most effective and efficient prompting procedure for use with clients in this population.

Method

Participants and Setting

Four male participants had permanent places at a special education school in Northern Ireland, which they attended 5.5 h per day, 5 days per week, 9 months of the year. Consent to conduct this experiment was granted by the University's Research Ethics Committee. Furthermore, informed consent and assent was obtained from the participants' parents and participants themselves, respectively. Table 1 contains participant information (name, gender, age, Peabody Picture Vocabulary Test score, Fourth Edition [PPVT™-4; Dunn and Dunn 2007], difference between age and PPVT-4 score, and diagnosis). The PPVT-4 is a norm referenced standardized test of receptive language. Participants ranged in age between 8.4 and 13.10 years and had PPVT-4 (A) scores across the narrower range of 5.7 to 7.11 years. They had been independently diagnosed, were screened for the presence of generalized identity matching skills, underwent preference assessments using the multiple stimulus without replacement protocol (MSWO; DeLeon and Iwata 1996), had no history of training with delayed prompting, and were able to attend to a table-top task for a minimum of 10 min. Experimental sessions were conducted in a separate classroom a short distance from the participants' main classroom.

Materials

The flags of 12 countries with corresponding country map outlines were individually printed and laminated onto 6 cm-by-5 cm cards (24 in total). Receptive conditional discriminations were taught using a MTS arrangement. A conditional (sample) stimulus was presented in isolation prior to presentation of a three-stimulus array comparison board (35 cm × 23.5 cm) containing one correct stimulus and two distractors. Comparison stimuli were fixed using Velcro strips to the board; positions were changed trial by trial to counter positional responding. The sample stimuli were country map outlines (black and white) containing country names; comparison stimuli were corresponding country flags (full color). All stimuli were physically distinct but conceptually related (e.g., flag of Sweden with map outline of Sweden).

Four different stimulus sets were quasi-randomly assigned to one of four instructional conditions (5-s PPD; 5-s CPD; 2-s CPD; T&E). Stimulus set assignment was counterbalanced across participants. Stimulus sets were randomly combined from an online atlas using a standard search engine and modified using Microsoft Word®. A logical analysis (Gast 2009) was used to approximate stimulus set difficulty. Dimensions logically analyzed were (a) number of colors per flag (maximum of 3), (b) similarity of colors and featured lines, and (c) number of symbols within a flag set. One session consisted of nine trials and was recorded using a Flip MinoHD digital camera with tripod. Pre-determined reinforcers, data collection sheets, and a token board consisting of nine tokens were used across all participants.

Dependent Measures

Direct comparisons between instructional conditions were made using effectiveness and efficiency data. Effectiveness refers to an instructional condition producing responding to mastery criterion level. Mastery criterion was defined as eight or nine (89%>) independent or prompted correct responses (+ or + p) made for three consecutive sessions, inclusive of one

Table 1 Participant information

Name	Sex	Age (year/month)	PPVT (A) score (year/month)	Age minus PPVT ^a	Diagnosis
Brian	M	8.4	7.11	0.5	MLD ^b + SPLD ^c + SEBD ^d
Aaron	M	13.10	6.7	7.3	MLD + ASD ^e
David	M	8.11	6.5	2.6	MLD + ASD
Alan	M	8.5	5.7	2.10	MLD

^a Difference between chronological age and PPVT score (PPVT™-4)

^b Moderate learning difficulty

^c Speech and language disorder

^d Social emotional behavior disorder

^e Autism spectrum disorder

Fig. 1 The y-axis depicts the number of correct independent responses, by each session (X-axis), for four participants with three prompt delays: progressive prompt delay (PPD, square symbols), constant prompt delay 2-s or 5-s (2-s CPD, triangles; 5-s CPD, circles), and trial-and-error (T&E, diamonds) conditions. When criterion was met, as denoted with a post-test (PT), maintenance probes (MP) were conducted after several weeks (WK). Note that a differential reinforcement contingency was in effect for David and for Alan only, during all instructional sessions (except for T&E), and maintenance probes

“no prompt” post-test (PT) session. Efficiency measures (Table 3) included number of training trials, number of errors, and percentage of errors to criterion. Equally effective conditions were ranked 1 to 4 based upon efficiency measures. Figure 1 shows independent correct responses by session and were used to chart each participants’ performance.

Inter-Observer Agreement and Procedural Integrity

Observers independent of this research retrospectively analyzed inter-observer agreement (IOA) and procedural integrity (PI) (Billingsley et al. 1980). This was done in 33% of sessions, across participant conditions. Prior to IOA and PI analysis, observers underwent training and were assessed in two practice sessions. All observers scored above 89% accuracy. The point-by-point method was used to calculate IOA for responses recorded (Ayres and Gast 2009). This was done by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100. Agreement averaged 99.4% (range 98–100%) across participants. PI was calculated by dividing the number of completed instructional trial components by the number of planned trial components and multiplying by 100. Average PI score was 96.8% (range 93–100%) across participants.

Experimental Design

A within-subject AATD was used to examine multiple experimental conditions simultaneously, targeting non-reversible behaviors, with a focus on delineating relative efficiencies

(Sindelar et al. 1985). This allowed for a direct comparison using effectiveness and efficiency measures in four experimental conditions during baseline, instruction, and maintenance.

Procedure

Pre-Baseline Assessment

All participants underwent assessment for a generalized identity match-to-sample (IDMTS) repertoire. Participants were presented samples that were physically identical to their corresponding S+ comparisons. No prompting occurred during IDMTS trials. A matching response was defined as “pointing to and touching the identical comparison stimulus.” Matching responses received a token (exchanged for an edible reinforcer on a FR3) and verbal praise (e.g., “Well done, great work!”).

Baseline

During baseline, novel stimulus sets were randomly assigned to one of four instructional conditions (5-s PPD, 5-s CPD, 2-s CPD, and T&E). One baseline session, consisting of nine trials, occurred for each of the stimulus sets to ensure training materials were equally difficult. A baseline trial consisted of a sequence of eight components, they included (a) establish eye contact, (b) present sample stimulus, (c) secure a differential observing response (DOR; touching sample stimulus), (d) present comparison array, (e) await learner response (up to 8 s), (f) provide contingent reinforcement, (g) removal of materials, and (h) observe a 3- to 5-s inter-trial interval (ITI).

Instruction

As no scores in baseline exceeded 70% correct, instruction sessions employed the same stimuli as used in the baseline session. An instructional trial included nine components: (a) establish eye contact, (b) present sample stimulus, (c) secure DOR to sample stimulus, (d) present three-stimulus comparison array, (e) prompt according to condition and prompt level, (f) await learner response (for up to 8 s), (g) provide contingent reinforcement, (h) removal of materials, and (i) observe a 3- to 5-s ITI. A gestural prompt was used here; the experimenter pointed to the correct stimulus in the array; no verbal instruction or verbal prompts were used.

Responses were recorded in one of five possible ways at the conclusion of a trial. Independent correct or incorrect responses were scored dichotomously using plus or minus symbols (+ or –). These were defined as the participant pointing to and touching a S+, or a distractor (S–), respectively. If two comparison stimuli were touched, then the trial ended and was scored (–). Prompted correct responses (recorded as + p), or incorrectly prompted response (– p) were defined in the same

Table 2 Prompt levels for each of the instructional conditions used.

Prompt level	5-s PPD	5-s CPD	2-s CPD	T&E
Level 0	0-s delay	0-s delay	0-s delay	0-s ^a delay
Level 1	1-s delay	5-s delay	2-s delay	
Level 2	2-s delay			
Level 3	3-s delay			
Level 4	4-s delay			
Level 5	5-s delay			
Post-test	No prompt	No prompt	No prompt	No prompt

^a 0-s prompting occurred for the first session only

manner as outlined above but with the inclusion of a gestural prompt prior to response emission. Failures to respond at all were recorded as NR. Errors were recorded (–) but ignored by the experimenter, signaling the end of a trial.

Four sessions were conducted daily, two in the morning and two in the afternoon, one from each of the conditions, 5-s PPD, 5-s CPD, 2-s CPD, and T&E. All instruction sessions contained nine trials from the designated condition. Sessions were conducted on a one-to-one basis by the first author. Sessions were separated from each other by a minimum of 15 min. Condition order of presentation was quasi-randomly determined prior to the experiment. Prompt levels used across conditions are shown in Table 2. A no prompt post-test session followed the same protocol described for baseline.

Trial-and-Error Condition

The first session in the T&E condition used zero-second prompting (0-s delay), and all subsequent sessions followed the baseline protocol (components a to h) described above. Reinforcement was provided on an FR1 schedule for all correct responses, and no prompting was provided.

Prompting Levels

A zero-second delay level (Table 2) trial contained components (a) through (i), outlined in the instruction section above. At step (e), following presentation of the comparison array, the experimenter immediately provided a gestural prompt to the S+. Criteria to move between the prompting levels of a condition were as follows: if eight or nine independent or prompted correct responses occur in one session, increase level for next session; and if two consecutive errors or three total errors occur in one session, decrease prompt level for next session.

Reinforcement

Potential reinforcers were initially determined through teacher nomination and then by participant choice using an MSWO protocol (DeLeon and Iwata 1996). A range of small edible reinforcers were selected from a pool at the beginning of all sessions. In baseline, reinforcement delivery was contingent on correct responding; no prompting was available. The purpose of the AATD was to compare relative efficiencies of instructional conditions, not reinforcement effectiveness. Reinforcement during baseline preserves this function (Gast 2009, p. 360). During instruction for Brian and Aaron, prompted and independent correct responses both resulted in verbal praise and a token. Tokens could be exchanged for an edible on a fixed ratio (FR3) schedule. Differential reinforcement was applied to David and Alan's PD conditions.

Differential Reinforcement

DR was applied to David and Alan's PD conditions only. This modification was based on findings from a pilot study, not reported here, which showed both to be prompt dependent. This procedure favored independent responses by using an FR1 schedule of reinforcement for independent correct responses versus an FR3 schedule for prompted correct responses. Once learners had accrued three tokens, these tokens could then be exchanged for a preferred edible reinforcer, while independent correct responses received an edible and verbal praise immediately (FR1). This approach has been used effectively with similar types of non-learners previously and aims to shift responding that is dependent on a prompt to responding under the control of the sample stimulus (Cividini-Motta and Ahearn 2013; Hausman et al. 2014; Vladescu and Kodak 2010; Wolery et al. 1992).

Maintenance

Maintenance sessions, as seen in Fig. 1, were conducted for Brian and Aaron at 2-, 4-, 6- and 8-week intervals. For David, they were conducted at 2-, 4-, 6-, and 7-week intervals, and for Alan, 2-, 4-, and 7-week intervals. These sessions followed the same protocol as that outlined above for baseline, and no prompting was provided.

Results

Figure 1 shows mastery level criterion was attained in all conditions and by all four participants. At baseline, participant performances were not beyond 70% accuracy in any instructional condition (range 22–66%). During instruction, Brian's correct independent responses increased rapidly to mastery level in all instructional conditions, with T&E ranked first (this is likely explained due to the saliency of one training stimulus associated with T&E and is discussed later). Brian maintained criterion level in all of his instructional conditions at 2-, 4-, 6- and 8-week intervals post-mastery. Aaron, Alan, and David's performance shared some similarity in that for all, the 5-s PPD condition was ranked first requiring the least number of training trials and/or errors to criterion (Table 3). Aaron's data showed a greater degree of variability across his instructional conditions', specifically, in the 5-s CPD condition. This may have been due to him requiring a prompt to the S+ sooner than the delay value prescribed in this condition. This is evidenced by a return to zero-second prompting every second session. Following mastery, Aaron maintained this criterion level in all conditions at 2-, 4-, 6-, and 8-week intervals. For David, performance across all conditions proceeded in a steady upward trajectory to mastery criterion with little variability evident, except that T&E took longest. Post-

mastery criterion responding was maintained at 2- and 6-week intervals post-mastery, but lower in 5-s PPD in weeks 4 and 7 post-mastery. Alan's performance shows the most variability in the 2-s CPD condition. DR was being applied to this condition, with the resultant effect of him attempting to respond, in error, prior to the prompt because once the prompt was delivered, edible reinforcement would only follow at the culmination of three tokens (FR3). For conditions with a low delay value, this delay to reinforcement should be considered. However, mastery was eventually attained in all of Alan's conditions and subsequently maintained at 2 and 7 weeks post-mastery. For Alan, week 4 post-mastery performance in the 5-s PPD condition produced six independent correct responses and was below mastery criterion. However, this performance recovered to 100% at week 7.

Table 3 shows combined effectiveness and efficiency data for all participants. All instructional conditions proved successful at producing mastery level criterion for all four participants, of whom David and Alan had an additional DR procedure in place for all of their PD conditions. Brian's efficiency data (top panel of Table 3 and Fig. 1) show his conditions were ranked as follows in terms of number of trials taken to criterion (with

percentage of errors in that condition): T&E (0%), 5-s CPD (2.8%), 2-s CPD (0%), and 5-s PPD (0%). For Brian, only one error occurred during training (5-s CPD); this was the exception rather than the rule. For the remaining participants, T&E consistently produced the highest percentage of errors. Aaron's instructional conditions were ranked as follows: 5-s PPD (1.9%), 2-s CPD (8.6%), T&E (16.7%), and 5-s CPD (14.6%). David's conditions were ranked as 5-s PPD (6.7%), 5-s CPD (15.6%), 2-s CPD (12.1%), and T&E (18.3%). For Alan, performance ranked by condition was as follows: 5-s PPD (7.9%), 5-s CPD (16.3%), T&E (20.4%), and 2-s CPD (11.6%). For these three participants, the 5-s PPD was consistently ranked first in terms of trials to criterion, with the T&E condition producing the highest percentage of errors before criterion performance was reached.

Summary data, shown in Fig. 2, illustrate the large mean differences across conditions. On average, the 5-s PPD condition was much more efficient at skill delivery: mean training trials to criterion was 65.25 for the 5-s PPD condition versus 110.25 for T&E. Similarly, during instruction, the 5-s PPD condition produced the lowest mean percentage of errors (5%), and the T&E condition was the highest (17%).

Table 3 Effectiveness and efficiency data for four participants across four instructional conditions (baseline data is excluded). For Alan and David all PD conditions included a differential reinforcement (DR) procedure

Participant/condition	No. of training trials	Total errors	% errors	Indep. correct	Rank	Mastery
Brian						
5-s PPD	54	0	0.0%	38	4	Yes
5-s CPD	36	1	2.8%	34	2	
2-s CPD	45	0	0.0%	35	3	
T&E	36	0	0.0%	30	1	
Total/average	171	1 ^a	0.9% ^a	107 ^a		
Aaron						
5-s PPD	54	1	1.9%	40	1	Yes
5-s CPD	144	21	14.6%	80	4	
2-s CPD	81	7	8.6%	45	2	
T&E	90	15	16.7%	72	3	
Total/average	369	29 ^a	8.4% ^a	165 ^a		
David (DR)						
5-s PPD	90	6	6.7%	53	1	Yes
5-s CPD	90	14	15.6%	68	2	
2-s CPD	99	12	12.1%	66	3	
T&E	153	28	18.3%	124	4	
Total/average	432	32 ^a	11.4% ^a	187 ^a		
Alan (DR)						
5-s PPD	63	5	7.9%	35	1	Yes
5-s CPD	135	22	16.3%	90	2	
2-s CPD	189	22	11.6%	100	4	
T&E	162	33	20.4%	124	3	
Total/average	549	49 ^a	12.0% ^a	225 ^a		

^a Total/average data exclude T&E condition

Fig. 2 Mean number of training trials and percentage of errors (y-axis) to mastery criterion level for all four participants across all four conditions (x-axis)

Discussion

The present investigation directly compared three variations of PD (5-s PPD, 5-s CPD, and 2-s CPD) alongside T&E instruction and extends the one published study to have compared progressive and constant PD (Ault et al. 1988). Some differences between the Ault et al. study and this one do exist and will be discussed in due course. The present investigation set out to answer three experimental questions: (1) to determine which of these procedures was effective, (2) to identify which procedure was associated with the least number of training trials and errors to criterion, and (3) to provide clinicians with some preliminary evidence in support of the most effective and efficient prompting procedure for use with clients in this population. The AATD has been widely used in recent research to address similar questions to the ones posed here. For example, Leaf et al. (2016) compared most-to-least prompting to an error correction procedure involving feedback and remedial trials for teaching two children with ASD to use receptive labels, and Gutierrez et al. (2016) used an AATD to assess the effects of video prompting with and without voice-over narration on the play skills of two young children with ASD. It is thus the single-subject design of choice for comparisons of specific procedural strategies.

In relation to the first research question, all instructional conditions were shown to be effective in producing acquisition to the mastery criterion for all participants and this is consistent with previous research that shows PD to be an effective form of instruction (Handen and Zane 1987; Walker 2008; Wolery et al. 1992). Efficiency data allowed for a more sophisticated analysis and was used to address the second question. For three out of four participants, 5-s PPD was ranked first and from all four conditions, 5-s PPD was most efficient in terms of mean training trials to criterion and percentage of errors to criterion (Fig. 2). For one participant (Brian), T&E was ranked first and this was likely due to a preference the participant had demonstrated for the Welsh

flag. This flag was part of the stimulus set for him in the T&E condition. Contrastingly, T&E instruction was ranked either third or fourth for the remaining participants, and overall was least efficient, producing the highest mean score and percentage on both measures.

Outcomes in relation to efficiency are entirely consistent with published experimental studies (Doyle et al. 1990; Flores et al. 2006; Heal et al. 2009; Heckaman et al. 1998; Hoch et al. 2009; Wolery et al. 1990a; Wolery et al. 1990b) and reviews of the literature (Handen and Zane 1987; Walker 2008; Wolery et al. 1992). These have demonstrated both the PPD and CPD procedures to be effective and efficient at producing acquisition in learners with ASD/ID, and with few errors. Additionally, few studies have compared the use of a 2-s CPD procedure. An exception is Libby et al. (2008) who combined a 2-s delay with an MTL instructional procedure and produced acquisition of the training tasks with a low frequency of errors. Libby et al. (2008) concluded that the 2-s MTL condition represented the best default strategy for learners with ASD. This unique procedural combination offered the best compromise between rapidity of learning and frequency of learner errors. Other researchers have used 4-s (Doyle et al. 1990) and 3-s (Mechling et al. 2007) CPD effectively. It should be noted that the 2-s delay used here provided only a brief opportunity for learners to respond before the addition of a prompt. For learners with a baseline response latency higher than this delay value, prompt dependence (Fisher et al. 2007) may become an issue. For example, learners may simply learn to wait for delivery of a prompt and receive the same level of reinforcement delivered for an independent correct response. Therefore, practitioners who use the 2-s delay value with CPD should be aware of the potential for this development.

Prompt dependence has been observed in the literature previously and is not limited to PD-based instruction. LTM prompting (Fisher et al. 2007) has also produced responding under the control of extra-stimulus prompts rather than within-

stimulus cues (Brown and Mirenda 2006; Cameron et al. 1992). Previous research has shown that stimulus manipulation procedures, involving incremental changes of the stimulus complex (Graff and Green 2004), and DR procedures favoring independent versus prompted correct responses have proved successful in bringing about acquisition in previously prompt-dependent learners (Cividini-Motta and Ahearn 2013; Fisher et al. 2007; Hausman et al. 2014; Karsten and Carr 2009; Touchette and Howard 1984; Vladescu and Kodak 2010; Wolery et al. 1992). Alig-Cybrivsky et al. (1990) improved performance by adding DR to a 3-s CPD procedure for three out of four participants. Additionally, researchers have shown DR to be effective on 83% of occasions in which it was used (Wolery et al. 1992). Although we did not examine DR experimentally, a limitation of the present study, David and Alan were both prompt dependent in an identical pilot study conducted immediately prior to this one, with the exception of stimuli differences. Findings here for David and Alan show all conditions were effective at bringing learner performance to mastery criterion level when DR was added to PD. DR was therefore effective at bringing previously prompt-dependent participants (David and Alan) to mastery.

Ault et al. (1988) compared two conditions (8-s PPD and 5-s CPD) using three participants solely diagnosed with an ID. The present study is an extension of Ault et al.'s work in that we enrolled four learners diagnosed with ASD and/or ID (see Table 1) and compared four instructional procedures simultaneously using an AATD—two more conditions than previously compared. This investigation was motivated by the common use of PD in clinical practice, despite a lack of efficiency-based evidence supporting either version in this population (Walker 2008). It is important to compare multiple procedural variations with each other to determine which of these is most efficient (Carroll et al. 2015; Reichow and Wolery 2011). Although little difference separates these conditions at the individual level, a finding consistent with that of Ault et al. (1988), when we combine and average trials to criterion and percentage of errors, by condition (Fig. 2), more pronounced differences between conditions are observed: 5-s PPD is effective and the most efficient regarding mean trials to criterion and on errors to criterion, with T&E ranked least effective. This finding is in contrast to those of Ault et al. (1988); their study favored 5-s CPD over 8-s PPD. However, there are a number of differences between the studies. For example, the delay value used by Ault et al. (1988) for the PPD procedure was 8 s rather than the more widely used 5-s delay value. In addition, task differences are salient: Ault et al. used an expressive labeling task in their experiment, whereas the present study used receptive conditional discriminations taught in an MTS arrangement. Unfortunately, the scarcity of comparison-driven investigations of this type limit our ability to contrast

the outcome data fully but does emphasize the need for further comparative research similar to that reported on here (Handen and Zane 1987).

Finally, this study provides a basis for some recommendations for clinicians who use PD in their day-to-day practice. Overall, as compared with 2-s CPD, 5-s CPD, and T&E, 5-s PPD produced acquisition in the least mean number of training trials and with fewest errors (Fig. 2). Thus, we conclude that while an individualized procedure may subsequently be needed, in the absence of other information, clinicians should consider using a 5-s PPD procedure before moving on to other forms of delay-based prompting. This procedure was shown to mitigate errors, is responsive to the performance of the learner during acquisition, and is readily modified to incorporate DR if required (a procedure which has been shown to be effective with prompt-dependent learners, see Cividini-Motta and Ahearn 2013).

Future Directions

An interesting avenue for future research and practice would be to examine learners' preferences for prompting strategies, by allowing participants to experience a number of instructional procedures and then to choose a preferred instructional procedure (cf. Heal et al. 2009). The effect of such choice on trials and errors to mastery criterion could then be assessed. Relatedly, teachers' preferences for implementing one or other strategy could be acted upon.

Acknowledgements We would like to acknowledge the help and support of those who conducted IOA and PI checks of experimental sessions.

Funding Funding was provided through a Department for Employment and Learning PhD Studentship, Northern Ireland, to the first author. That body had no involvement in the design or execution of the study.

Compliance with Ethical Standards

Consent to conduct this experiment was granted by the University's Research Ethics Committee. Furthermore, informed consent and assent was obtained from the participants' parents and participants themselves, respectively.

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

References

- Alig-Cybrivsky, C., Wolery, M., & Gast, D. L. (1990). Use of a constant time delay procedure in teaching preschoolers in a group format. *Journal of Early Intervention*, 14(2), 99–116. <https://doi.org/10.1177/105381519001400201>.
- Ault, M. J., Gast, D. L., & Wolery, M. (1988). Comparison of progressive and constant time-delay procedures in teaching community-sign word reading. *American Journal on Mental Retardation*, 93(1),

- 11–56 Retrieved from <http://psycnet.apa.org/psycinfo/1989-10170-001>.
- Ayres, K. M., & Gast, D. L. (2009). Dependent measures and measurement procedures. In: D. L. Gast (Ed.), *Single Subject Research Methodology in Behavioural Sciences*. New York: Routledge. <https://doi.org/10.4324/9780203877937>.
- Bennett, D. L., Gast, D. L., Wolery, M., & Schuster, J. W. (1986). Time delay and system of least prompts: a comparison in teaching manual sign production. *Education and Training of the Mentally Retarded*, 21, 117–129.
- Billingsley, F. F., White, O., & Munson, R. (1980). Procedural reliability: a rationale and an example. *Behavioral Assessment*, 2, 229–241.
- Brown, K. E., & Mirenda, P. (2006). Contingency mapping: use of a novel visual support strategy as an adjunct to functional equivalence training. *Journal of Positive Behavior Interventions*, 8(3), 155–164. <https://doi.org/10.1177/10983007060080030401>.
- Cameron, M. J., Ainsleigh, S. A., & Bird, F. L. (1992). The acquisition of stimulus control of compliance and participation during an ADL routine. *Behavioral Interventions*, 7(5), 327–340. <https://doi.org/10.1002/bin.2360070502>.
- Carroll, R. A., Joachim, B. T., St. Peter, C. C., & Robinson, N. (2015). A comparison of error-correction procedures on skill acquisition during discrete-trial instruction. *Journal of Applied Behavior Analysis*, 48(2), 257–273. <https://doi.org/10.1002/jaba.205>.
- Cividini-Motta, C., & Ahearn, W. H. (2013). Effects of two variations of differential reinforcement on prompt dependency. *Journal of Applied Behavior Analysis*, 46(3), 640–650. <https://doi.org/10.1002/jaba.67>.
- Coleman-Martin, M. B., & Heller, K. W. (2004). Using a modified constant prompt-delay procedure to teach spelling to students with physical disabilities. *Journal of Applied Behavior Analysis*, 37(4), 469–480. <https://doi.org/10.1901/jaba.2004.37-469>.
- Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied behavior analysis*. Upper Saddle River, NJ: Pearson/Merrill-Prentice Hall.
- DeLeon, I. G., & Iwata, B. a. (1996). Evaluation of a multiple-stimulus presentation format for assessing reinforcer preferences. *Journal of Applied Behavior Analysis*, 29(4), 519–532. <https://doi.org/10.1901/jaba.1996.29-519>.
- Demchak, M. (1990). Response prompting and fading methods: a review. *American Journal on Mental Retardation*, 94(6), 603–615.
- Doyle, P. M., Wolery, M., Gast, D. L., Ault, M. J., & Wiley, K. (1990). Comparison of constant time delay and the system of least prompts in teaching preschoolers with developmental delays. *Research in Developmental Disabilities*, 11(1), 1–22. [https://doi.org/10.1016/0891-4222\(90\)90002-P](https://doi.org/10.1016/0891-4222(90)90002-P).
- Dunn, D. M., & Dunn, L. M. (2007). *Peabody picture vocabulary test, fourth edition manual (PPVT-4)*. Minneapolis: NCS Pearson, Inc..
- Fentress, G. M., & Lerman, D. C. (2012). A comparison of two prompting procedures for teaching basic skills to children with autism. *Research in Autism Spectrum Disorders*, 6(3), 1083–1090. <https://doi.org/10.1016/j.rasd.2012.02.006>.
- Fisher, W. W., Kodak, T., & Moore, J. W. (2007). Embedding an identity-matching task within a prompting hierarchy to facilitate acquisition of conditional discriminations in children with autism. *Journal of Applied Behavior Analysis*, 40(3), 489–499. <https://doi.org/10.1901/jaba.2007.40-489>.
- Flores, M. M., Houchins, D. E., & Shippen, M. E. (2006). The effects of constant time delay and strategic instruction on students with learning disabilities' maintenance and generalization. *International Journal of Special Education*, 21(3), 45–57.
- Gast, D. L. (2009). *Single subject research methodology in behavioral sciences*. New York: Routledge. <https://doi.org/10.4324/9780203877937>.
- Godby, S., Gast, D. L., & Wolery, M. (1987). A comparison of time delay and system of least prompts in teaching object identification. *Research in Developmental Disabilities*, 8(2), 283–305. [https://doi.org/10.1016/0891-4222\(87\)90009-6](https://doi.org/10.1016/0891-4222(87)90009-6).
- Graff, R. B., & Green, G. (2004). Two methods for teaching simple visual discriminations to learners with severe disabilities. *Research in Developmental Disabilities*, 25(3), 295–307. <https://doi.org/10.1016/j.ridd.2003.08.002>.
- Green, G. (2001). Behavior analytic instruction for learners with autism: advances in stimulus control technology. *Focus on Autism and Other Developmental Disabilities*, 16(2), 72–85. <https://doi.org/10.1177/108835760101600203>.
- Gutierrez, A., Bennett, K. D., McDowell, L. S., Cramer, E. D., & Crocco, C. (2016). Comparison of video prompting with and without voice-over narration: a replication with young children with autism. *Behavioral Interventions*, 31(4), 377–389. <https://doi.org/10.1002/bin.1456>.
- Handen, B. L., & Zane, T. (1987). Delayed prompting: a review of procedural variations and results. *Research in Developmental Disabilities*, 8(2), 307–330. [https://doi.org/10.1016/0891-4222\(87\)90010-2](https://doi.org/10.1016/0891-4222(87)90010-2).
- Hausman, N. L., Ingvarsson, E. T., & Kahng, S. (2014). A comparison of reinforcement schedules to increase independent responding in individuals with intellectual disabilities. *Journal of Applied Behavior Analysis*, 47(1), 155–159. <https://doi.org/10.1002/jaba.85>.
- Heal, N. A., Hanley, G. P., & Layer, S. (2009). An evaluation of the relative efficacy of children's preferences for teaching strategies that differ in amount of teacher directedness. *Journal of Applied Behavior Analysis*, 42(1), 123–143. <https://doi.org/10.1901/jaba.2009.42-123>.
- Heckaman, K., Alber, S., Hooper, S., & Heward, W. (1998). A comparison of least-to-most prompts and progressive time delay on the disruptive behavior of students with autism. *Journal of Behavioral Education*, 8(2), 171–201. <https://doi.org/10.1023/A:1022883523915>.
- Hoch, H., Taylor, B. A., & Rodriguez, A. (2009). Teaching teenagers with autism to answer cell phones and seek assistance when lost. *Behavior Analysis in Practice*, 2(1), 14–20. <https://doi.org/10.1007/BF03391733>.
- Karsten, A. M., & Carr, J. E. (2009). The effects of differential reinforcement of unprompted responding on the skill acquisition of children with autism. *Journal of Applied Behavior Analysis*, 42(2), 327–334. <https://doi.org/10.1901/jaba.2009.42-327>.
- Leaf, J. B., Alcala, A., Leaf, J. A., Tsuji, K., Kassardjian, A., Dale, S., McEachin, J., Taubman, M., & Leaf, R. (2016). Comparison of most-to-least to error correction for teaching receptive labelling for two children diagnosed with autism. *Journal of Research in Special Educational Needs*, 16(4), 217–225. <https://doi.org/10.1111/1471-3802.12067>.
- Libby, M. E., Weiss, J. S., Bancroft, S., & Ahearn, W. H. (2008). A comparison of most-to-least and least-to-most prompting on the acquisition of solitary play skills. *Behavior Analysis In Practice*, 1(1), 37–43. <https://doi.org/10.1007/BF03391719>.
- Mechling, L. C., Gast, D. L., & Krupa, K. (2007). Impact of SMART board technology: an investigation of sight word reading and observational learning. *Journal of Autism and Developmental Disorders*, 37(10), 1869–1882. <https://doi.org/10.1007/s10803-007-0361-9>.
- National Autism Center. (2009). The National Standards Project: addressing the need for evidence-based practice guidelines for autism spectrum disorder. Randolph, Mass.: *National Autism Center*.
- Odom, S. L., Collet-Klingenberg, L., Rogers, S. J., & Hatton, D. D. (2010). Evidence-based practices in interventions for children and youth with autism spectrum disorders. *Preventing School Failure: Alternative Education for Children and Youth*, 54(4), 275–282. <https://doi.org/10.1080/10459881003785506>.
- Reichow, B., & Wolery, M. (2011). Comparison of progressive prompt delay with and without instructive feedback. *Journal of Applied*

- Behavior Analysis*, 44(2), 327–340. <https://doi.org/10.1901/jaba.2011.44-327>.
- Saunders, K. J., & Spradlin, J. E. (1990). Conditional discrimination in mentally retarded adults: The development of generalized skills. *Journal of the Experimental Analysis of Behavior*, 54(3), 239–250. <https://doi.org/10.1901/jeab.1990.54-239>.
- Schilmoeller, G. L., Schilmoeller, K. J., Etzel, B. C., & LeBlanc, J. M. (1979). Conditional discrimination after errorless and trial-and-error training. *Journal of the Experimental Analysis of Behavior*, 31(3), 405–420. <https://doi.org/10.1901/jeab.1979.31-405>.
- Schuster, J. W., Gast, D. L., Wolery, M., & Guiltinan, S. (1988). The effectiveness of a constant time-delay procedure to teach chained responses to adolescents with mental retardation. *Journal of Applied Behavior Analysis*, 21(2), 169–178. <https://doi.org/10.1901/jaba.1988.21-169>.
- Schuster, J. W., Griffen, A. K., & Wolery, M. (1992). Comparison of simultaneous prompting and constant time delay procedures in teaching sight words to elementary students with moderate mental retardation. *Journal of Behavioral Education*, 2(3), 305–325. <https://doi.org/10.1007/BF00948820>.
- Sindelar, P., Rosenberg, M., & Wilson, R. (1985). An adapted alternating treatments design for instructional research. *Education & Treatment of Children*, 8(1), 67–76. Retrieved from <http://www.jstor.org/stable/42898888>.
- Snell, M. E. (1982). Analysis of time delay procedures in teaching daily living skills to retarded adults. *Analysis and Intervention in Developmental Disabilities*, 2(2–3), 139–155. [https://doi.org/10.1016/0270-4684\(82\)90015-5](https://doi.org/10.1016/0270-4684(82)90015-5).
- Snell, M. E., & Gast, D. L. (1981). Applying time delay procedure to the instruction of the severely handicapped. *Research and Practice for Persons with Severe Disabilities*, 6(3), 3–14. <https://doi.org/10.1177/154079698100600301>.
- Soluaga, D., Leaf, J. B., Taubman, M., McEachin, J., & Leaf, R. (2008). A comparison of flexible prompt fading and constant time delay for five children with autism. *Research in Autism Spectrum Disorders*, 2(4), 753–765. <https://doi.org/10.1016/j.rasd.2008.03.005>.
- Terrace, H. S. (1963a). Discrimination learning with and without “errors”. *Journal of the Experimental Analysis of Behavior*, 6, 1–27. <https://doi.org/10.1901/jeab.1963.6-1>.
- Terrace, H. S. (1963b). Errorless transfer of a discrimination across two continua. *Journal of the Experimental Analysis of Behavior*, 6, 223–232. <https://doi.org/10.1901/jeab.1963.6-223>.
- Touchette, P. E. (1968). The effects of graduated stimulus change on the acquisition of a simple discrimination in severely retarded boys. *Journal of the Experimental Analysis of Behavior*, 11(1), 39–48. <https://doi.org/10.1901/jeab.1968.11-39>.
- Touchette, P. E. (1971). Transfer of stimulus control: measuring the moment of transfer. *Journal of the Experimental Analysis of Behavior*, 15(3), 347–354. <https://doi.org/10.1901/jeab.1971.15-347>.
- Touchette, P. E., & Howard, J. S. (1984). Errorless learning: reinforcement contingencies and stimulus control transfer in delayed prompting. *Journal of Applied Behavior Analysis*, 17(2), 1307932–1307188. <https://doi.org/10.1901/jaba.1984.17-175>.
- Vladescu, J. C., & Kodak, T. (2010). A review of recent studies on differential reinforcement during skill acquisition in early intervention. *Journal of Applied Behavior Analysis*, 43(2), 351–355. <https://doi.org/10.1901/jaba.2010.43-351>.
- Walker, G. (2008). Constant and progressive time delay procedures for teaching children with autism: a literature review. *Journal of Autism and Developmental Disorders*, 38(2), 261–275. <https://doi.org/10.1007/s10803-007-0390-4>.
- Weeks, M., & Gaylord-Ross, R. J. (1981). Task difficulty and aberrant behavior in severely handicapped students. *Journal of Applied Behavior Analysis*, 14(4), 449–463. <https://doi.org/10.1901/jaba.1981.14-449>.
- Wolery, M., & Gast, D. L. (1984). Effective and efficient procedures for the transfer of stimulus control. *Topics in Early Childhood Special Education*, 4(3), 52–77. <https://doi.org/10.1177/027112148400400305>.
- Wolery, M., Ault, M. J., Gast, D. L., Doyle, P. M., & Mills, B. M. (1990a). Use of choral and individual attentional responses with constant time delay when teaching sight word reading. *Remedial and Special Education*, 11(1), 47–58. <https://doi.org/10.1177/074193259001100509>.
- Wolery, M., Ault, M. J., Gast, D. L., Munson-Doyle, P., & Griffen, A. (1990b). Comparison of constant time delay and the system of least prompts in teaching chained tasks. *Education and Training of the Mentally Retarded*, 25, 243–257.
- Wolery, M., Holcombe, A., Cybriwsky, C., Doyle, P. M., Schuster, J. W., Ault, M. J., & Gast, D. L. (1992). Constant time delay with discrete responses: a review of effectiveness and demographic, procedural, and methodological parameters. *Research in Developmental Disabilities*, 13(3), 239–266. [https://doi.org/10.1016/0891-4222\(92\)90028-5](https://doi.org/10.1016/0891-4222(92)90028-5).
- Wolery, M., Munson-Doyle, P. M., Gast, D. L., Ault, M. J., & Simpson, S. L. (1993). Comparison of progressive time delay and transition-based teaching with preschoolers who have developmental delays. *Journal of Early Intervention*, 17(2), 160–176. <https://doi.org/10.1177/105381519301700207>.
- Wong, C., Odom, S. L., Hume, K., Cox, A. W., Fettig, A., Kucharczyk, S., ... Schultz, T. R. (2015). Evidence-based practices for children, youth, and young adults with autism spectrum disorder: a comprehensive review. *Journal of Autism and Developmental Disorders*, 45(7), 1951–1966. doi:<https://doi.org/10.1007/s10803-014-2351-z>.