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A REVIEW OF ERROR CORRECTION PROCEDURES DURING INSTRUCTION FOR CHILDREN WITH DEVELOPMENTAL DISABILITIES

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Error correction procedures are remedial strategies presented following an incorrect response that increases the probability that a correct response will occur in the future. Error correction is commonly used during skill acquisition programs for children with developmental disabilities; however, the specific strategy used may differ considerably. Recent comparative studies have examined the effect of numerous error correction procedures on the efficiency of acquisition for children with developmental disabilities. Despite considerable merit, minor procedural differences and unique terms for similar procedures likely affect comparisons across studies. Here, we clarify the procedures and findings of these studies and suggest areas of future research.

Key words: developmental disabilities, discrimination, error correction, review, skill acquisition

Learners with developmental disabilities may frequently make errors during skill acquisition, and effective instructor responding is paramount to the development of stimulus control. Error correction procedures are commonly included in instructional programs for individuals with developmental disabilities, although procedures vary considerably across studies and clinical programs. Error correction may be defined as any remedial procedure presented following an incorrect response that increases the probability that a correct response will occur in the future (McGhan & Lerman, 2013). Common components of error correction procedures include presenting the correct response, differentially reinforcing the correct response, and arranging negative reinforcement contingencies following errors (e.g., repeated presentation of the trial).

Four recent comparative studies (Carroll, Joachim, St. Peter, & Robinson, 2015; Carroll, Owsiany, & Cheatham, 2018; Kodak et al., 2016; McGhan & Lerman, 2013) have extended prior research on error correction procedures that may be commonly used in clinical settings. These studies utilized experimental designs that allowed for comparisons of the effects of error correction procedures on the efficiency of acquisition for children with developmental disabilities. Four to five procedures were included in each study and similar terms were used to describe the procedures. However, slight procedural deviations and different measures of efficiency limit comparisons across studies. In this review, we describe and offer consistent terms for common procedures, synthesize the findings of these studies, and suggest areas of future research.

EFFICIENCY

Efficiency of acquisition is the variable of interest in each of the reviewed studies. The most efficient procedure is that which promotes responding at mastery level in the fewest number of sessions, trials, or minutes (Wolery et al., 1991). Three of the studies reported the total number of sessions, number of exposures

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(i.e., presentations of the discriminative stimulus) to mastery, and total training time to mastery (Carroll et al., 2015, 2018; Kodak et al., 2016), whereas the remaining study reported only the number of exposures to mastery (McGhan & Lerman, 2013). When determining the most efficient procedure, correspondence between the number of exposures and the other efficiency measures was observed for all (Carroll et al., 2015) or most (Carroll et al., 2018; Kodak et al., 2016) of the participants. Thus, we used the number of exposures to mastery to compare the findings across studies.

ERROR CORRECTION PROCEDURES

To synthesize the procedures that were common across the four comparative studies, we have proposed a uniform name for similar conditions and outlined study-specific variations in Table 1. We will refer to the conditions using the names in Table 1 for the remainder of the paper.

Error correction procedures are commonly described within a taxonomy of intrusiveness. McGhan and Lerman (2013) defined intrusiveness as "…the amount of additional responding required of the subject or therapist" (p. 628). The least intrusive error correction procedures are commonly used as control conditions and include differential reinforcement for correct responding or presenting an error statement (e.g., "No, that is not —"; see Table 1). Alternatively, some researchers program extinction following all responses as a control condition. Although extinction for all responses would not facilitate acquisition, the other procedures may promote the development of stimulus control, although they are likely inefficient. Additional error correction strategies include (a) demonstration,

Table 1
Procedures and Deviations across Studies

Condition name	Procedure following an error or no response	Variations
Control[a,b,c,d]	Therapist presents the next trial[a,b,c] or an error statement (i.e., "no that is not___").[d]	--
Demonstration[a,c,d]	Therapist demonstrates the correct response and removes the S+.[a,c,d]	--
Active Student Response (ASR)[a,b,c,d]	Therapist presents a prompt and requires the student to echo[a,b,c] or imitate[c,d] the prompt.	Re-present the prompt until a correct response is emitted.[a] Present a more intrusive (e.g., physical) prompt if errors occur during correction procedure.[d]
Remove and Re-present[b]	Following an error, the therapist removes the S+ and turns away for 2 s, re-presents the S+ with an immediate prompt, and only praise is delivered. [b] Following no response, the therapist prompts the correct response and delivers praise and a reinforcer.[b]	--
Re-present Until Correct[a,b,c]	Therapist presents a prompt and requires the student to echo[a,b] or imitate[c] the model. The therapist re-presents the S+ and an independent opportunity to respond.	Re-present the S+ once with an immediate prompt.[a] Re-present the S+ up to 10[c] or 20[b] trials or until an unprompted correct response.
Multiple Response Repetition[a,b,c]	Therapist presents a prompt and requires the student to echo[a,b,c] or imitate[c,d] the prompt, re-presents the S+, and…	Prompt the correct response for three trials.[a] Prompt the correct response for five trials or until 10[c] or 20[b] trials were presented. Present S+ until correct for three consecutive trials.[d]

Note. [a] Kodak et al. (2016), [b] Carroll et al. (2015), [c] Carroll et al. (2018), [d] McGhan & Lerman (2013); S+ = discriminative stimulus.

Table 2
Proposed Condition Names and Correspondences

Proposed Condition Name	Kodak et al. (2016) N = 5	Carroll et al. (2015) N = 5	Carroll et al. (2018) N = 4	McGhan & Lerman (2013) N = 5
Control	Differential Reinforcement (0/5)	Control (0/5)	No Error Correction (0/3)	Error Statement (0/5)
Demonstration	Demonstration (4/5)	--	Model (0/3)	Model (4/5)
Active Student Response (ASR)	Prompt Delay (1/5)	Single-Response Repetition (1/5)	Single-Response Repetition (3/3)	Active Student Response (0/1)
Remove and Re-present	--	Remove and Re-present (1/5)	--	--
Re-present Until Correct	Single Response Repetition (0/5)	Re-present Until Independent (3/5)	Re-present Until Independent (0/4)	--
Multiple Response Repetition	Multiple-Response Repetition (0/5)	Multiple-Response Repetition (0/5)	Multiple-Response Repetition (0/4)	Directed Rehearsal (0/5)

Note. The number of participants in each study whose responding met the mastery criterion in the fewest number of exposures, over the number of participants exposed to the condition is shown in parentheses. Participants with inconclusive findings across sets are not reported.

(b) active student response (ASR), (c) remove and re-present, (d) re-present until correct, and (e) multiple-response repetition (Table 1). Table 2 shows the number of participants who acquired the target responses in the fewest number of exposures over the total number of participants exposed to the condition in each study. McGhan and Lerman (2013) and Carroll et al. (2018) included within-participant replications, so we included the procedure that was most efficient for the majority of the comparisons. We excluded two participants (one from each study) as the most efficient procedure differed across comparisons. Of the total participants exposed to each condition, the demonstration condition was most efficient for 8 of 13 participants, ASR for 5 of 14 participants, remove and re-present for 1 of 5 participants, and re-present until correct for 3 of 14 participants. Neither the control nor multiple response repetition conditions were the most efficient for any participants.

EFFICIENT PROCEDURES

The demonstration condition was the most efficient procedure for the greatest number of participants and was included in three of the comparative studies (see Table 2). This procedure has been evaluated previously and was found to be less effective than ASR (Barbetta & Heward, 1993). The ASR condition was the most efficient strategy for five participants across three studies (Carroll et al., 2015; 2018; Kodak et al., 2016). Based on the description in Table 1, the apparent procedural difference between these conditions is the response requirement in the ASR condition. One reason why demonstration may be more efficient than ASR is the arrangement of differential reinforcement of unprompted correct responding. Specifically, differential reinforcement was arranged from the outset of instruction in the demonstration condition and following a set criterion in the ASR condition (e.g., following two sessions with at least 40% unprompted correct responses; Kodak et al., 2016). Future researchers might arrange differential reinforcement in the ASR condition from the outset of training, to assess whether this procedural difference may facilitate greater efficiency. Nonetheless, the efficient acquisition of targets in the demonstration condition may be unexpected (see McGhan & Lerman, 2013) and further analysis of this procedure is warranted.

Certain skill repertoires likely facilitate the acquisition of targets in the demonstration condition. Kodak et al. (2016) suggested that percentage of trials with echoics may be related to acquisition. Kodak et al. and Carroll et al. (2018) reported descriptive data, suggesting that the demonstration condition was most efficient for participants who echoed the demonstration during the greatest proportion of trials. Interestingly, McGhan and Lerman (2013) found that the demonstration condition was most efficient for four participants, even when the discriminative stimulus was not vocal (i.e., matching tasks). Future researchers should consider the repertoires (e.g., generalized imitation) that may facilitate acquisition in this condition. Moreover, descriptive data on echoics have only included the mean percentage of trials with echoics for the condition. Thus, it is unclear whether high levels of echoics were emitted at the outset of the demonstration condition or if echoics increased over time, potentially as a precurrent response (Polson & Parsons, 1994).

The remove and re-present procedure was the most efficient for one participant in Carroll et al. (2015). This study was the only study to include this procedure, which also included different consequences following an error or a no response (see Table 1). To the authors' knowledge, no prior study has evaluated differential reinforcement of no responses. Moreover, this procedure is similar to the ASR conditions with an added blackout period (i.e., the therapist turns away from the participant for 2 s). Future researchers might consider the differential effects of including punishment or differential reinforcement of no response as components of error correction procedures.

Finally, the re-present until correct condition includes a combination of negative and positive reinforcement contingencies, such that the trial is terminated only following a correct response, which also produces a programmed reinforcer. This condition was most efficient for three participants in the Carroll et al. (2015) study. However, two considerations should be made when interpreting these findings. First, this study did not include a demonstration condition. Carroll et al. (2018) did include a demonstration condition, and neither demonstration nor re-present until correct was identified as the most efficient procedure. Second, trials were presented until a correct response occurred or 20 trials were conducted. The authors do not report how frequently this termination criterion was met, information which might be critical in determining the mechanism responsible for the observed effects.

CONSIDERATIONS FOR ERROR CORRECTION

Idiosyncratic findings of efficiency may make it difficult for clinicians to select an error correction procedure. Two of the reviewed studies included additional variables for consideration: intrusiveness and preference. McGhan and Lerman (2013) suggest that more intrusive procedures may be aversive for the participant and result in lower therapist fidelity. The authors consistently found that less intrusive strategies (i.e., demonstration) were most efficient, suggesting that more intrusive procedures may not be necessary. Kodak et al. (2016) evaluated participants' preference for error correction procedures using a concurrent chains procedure (Hanley, 2010). In their study, two of the five participants showed a preference for the most efficient (demonstration) procedure, suggesting that participants' preferences may not always correspond with efficiency. This finding may not be surprising, however, as responding in the demonstration condition likely contacted lean schedules of reinforcement during early sessions. Finally, none of the reviewed studies included measures of social validity as rated by relevant stakeholders or measures of problem behavior. Future researchers should measure these variables alongside efficiency, intrusiveness, and preference.

Other variables, such as participants' existing repertoires and the skills being targeted, should also be considered when selecting an error correction procedure. In the reviewed studies, the majority of participants used multi-word utterances to communicate. One participant used single-word utterances and another used sign language using two-word phrases. Future research should include participants with less established vocal repertoires or participants who use alternative systems of communication. Moreover, the targeted skills included tacts for three participants, textuals for nine participants, auditory–visual conditional discriminations for six participants, and visual–visual conditional discriminations for one participant. Additional research should evaluate the effects of these error correction procedures on the acquisition of other operants (e.g., intraverbals).

FUTURE RESEARCH

Beyond the areas of research suggested above, researchers might evaluate novel error correction procedures or other procedural modifications (e.g., differential reinforcement, blackout periods, etc.) that may influence efficiency. Similarly, researchers should consider other definitions of efficiency (e.g., promoting greater generalization; see Wolery et al., 1991) and whether certain procedures might meet these definitions, despite requiring more exposures to mastery. For example, error correction that includes embedding mastered tasks (see Plaisance, Lerman, Laudont, & Wu, 2016) may promote greater maintenance, despite requiring similar or greater number of trials to mastery. Additional consideration might be given to procedures that are efficacious, but less efficient. In the reviewed studies, an average of three procedures was efficacious for participants; however, our review focused on the most efficient procedure. Future researchers should provide criteria for determining procedures that are "similarly efficient" for participants. Finally, researchers should identify the mechanisms underlying the effects of these procedures (see Rodgers & Iwata, 1991). The reviewed procedures included various reinforcement schedules, extinction, punishment, and other components that may affect stimulus control. Identifying the variables responsible for efficient acquisition has considerable implications for learning and warrants further pursuit.

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