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Replication of a Skills Assessment for Auditory–Visual Conditional Discrimination Training

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Abstract

Auditory–visual conditional discrimination training (e.g., receptive identification training, listener responses; AVCD) is ubiquitous in early intervention and special education programs. Nevertheless, some learners with Autism Spectrum Disorder (ASD) do not appear to benefit from this training despite use of empirically validated treatments. To prevent exposure to extended training that does not lead to learning, a skills assessment that measures skills related to AVCD training will be useful for educators and practitioners. The current study replicated the skills assessment developed and evaluated by Kodak et al. (2015) with 8 participants with ASD who received behavior analytic intervention that included at least 1 goal related to AVCD training. Two of the 8 participants mastered all skills included in the assessment except scanning. In addition, 5 participants' responding failed to reach mastery during subsequent exposure to AVCD training, which further demonstrated the predictive utility of the skills assessment.

Throughout the day, people encounter thousands of stimuli that require some type of differential responding. For example, a visual discrimination occurs when a parent who picks up her child from daycare approaches and hugs her own child rather than approaching and hugging an unknown child. Auditory discriminations also frequently occur, such as when a parent answers her phone when she hears the programmed daycare ring tone but not when she hears the standard ring tone. Due to the prevalence of these stimuli and the necessity of accurate differential responding to interact with our environment, behavior analysts frequently teach discriminations to individuals who do not acquire them through daily interactions and natural learning opportunities.

Children with Autism Spectrum Disorder (ASD) who receive comprehensive behavioral intervention are frequently exposed to discrimination training (Green, **2001**; Grow & LeBlanc, **2013**; LaMarca & LaMarca, **2018**). One type of discrimination that is targeted is a simple discrimination, which includes a three-term contingency (i.e., antecedent, behavior, and consequence). For example, an adult may say “clap”, the child claps his hands, and the adult provides enthusiastic praise. Another, more advanced type of discrimination taught to children with ASD is conditional discrimination. Conditional discrimination includes a four-term contingency in which a conditional stimulus and an antecedent stimulus collectively occasion a response which produces reinforcement. For example, a parent and child might look through a picture book of common animals, and the parent turns the page to reveal animals that live at a zoo. While the child is looking at the pictures (antecedent stimuli), the parent asks, “Where is the lion?” (the conditional stimulus), which alters the function of one of the pictures on the page. In this example, the picture of the lion becomes a discriminative stimulus and the other pictures become s-deltas. When the child touches the picture of the lion, the parent provides praise (e.g., “You found the lion! You are so smart.”).

Auditory-visual conditional discrimination (AVCD), as described in the previous example, includes an auditory sample stimulus (e.g., “Where is the lion?”) and visual antecedent stimuli (e.g., an array of pictures including a lion, zebra, monkey, hippo, and elephant). Many everyday tasks require an AVCD, and this type of discrimination (also referred to as receptive identification training, receptive labeling, and listener responses) is frequently targeted in comprehensive behavioral intervention programs and included in many early intervention curriculum manuals (e.g., Leaf & McEachin, 1999; Lovaas, **2003**;

Maurice et al., **2001**). In addition, AVCD training commonly occurs in special education settings and is included as an Individualized Education Program goal for most students with ASD (Kodak et al., **2018**).

Despite the prevalence of AVCD training in early intervention and special education programs for children with ASD, a proportion of these children may not readily acquire these discriminations during training. Special education teachers reported difficulty in establishing these discriminations in a proportion of students with ASD (Kodak et al., **2018**). In addition, Kodak et al. (**2015**) showed that 44% of participants with ASD did not acquire AVCD during exposure to typically efficacious intervention procedures. The authors developed a skills assessment to measure behavior that is related to AVCD. For example, during AVCD training, a learner should attend to and differentially respond to auditory stimuli (e.g., "cat," "dog," or "bird" across trials), scan and differentially respond to an array of visual stimuli (e.g., pictures of a cat, dog, and bird), match the auditory sample stimulus to the corresponding visual stimulus (i.e., match "cat" with a picture of a cat despite no physical similarity of stimuli), and respond to prompts delivered by the instructor (e.g., a model prompt) prior to and following errors. Therefore, the component discriminations required of the learner include an auditory discrimination (between samples), visual discrimination (between pictures in the array), and non-identity matching (matching auditory stimulus to visual stimulus; Kerr et al., **1977**).

Kodak et al. (**2015**) evaluated whether the outcomes of unsuccessful AVCD training were correlated with outcomes on a skills assessment that measured potential prerequisite skills for AVCD. Their skills assessment measured responding in five conditions: identity matching, imitation, visual discrimination, auditory discrimination, and scanning. Four of the nine participants did not engage in mastery level responding during one or more of the conditions included in the skills assessment. Following the skills assessment, all nine participants received AVCD training. Kodak et al. found that the skills assessment was predictive of successful AVCD training for all five participants who showed mastery of all conditions in the skills assessment. Further, the skills assessment accurately predicted unsuccessful AVCD training for two of the four participants who failed to master one or more conditions in the assessment. Thus, the skills assessment accurately differentiated between seven of the nine participants who may or may not acquire AVCD when exposed to efficacious AVCD training procedures without substantial procedural modifications.

Although the results of Kodak et al. (**2015**) provide initial evidence for the utility of an assessment to measure skills related to AVCD training, the assessment was not as predictive of unsuccessful AVCD training for two of the four participants who failed to master one or more conditions of the skills assessment. One participant (Amar) reached mastery during AVCD training without substantial procedural modifications despite failing to reach mastery of the auditory discrimination in the skills assessment. The other participant (Hal) reached mastery during AVCD training following substantial procedural modifications (lengthy exposure to blocking) despite failing to master three of the five conditions in the skills assessment. Therefore, additional replications with learners who are unlikely to master one or more conditions in the skills assessment are needed.

In clinical practice, the application of a skills assessment could prevent exposing learners to AVCD training that is unlikely to produce positive treatment outcomes. In addition, a skills assessment could identify component skills to teach before AVCD instruction, similar to other assessments used in comprehensive behavioral intervention (e.g., *Verbal Behavior Milestones Assessment and Placement Program*, VB-MAPP; Sundberg, **2008**). For these reasons, the skills assessment is most useful for identifying learners who are receiving behavior-analytic services and are unlikely to benefit from AVCD training, and replication of this skills assessment with additional learners with ASD is necessary.

The purpose of the current study was to improve upon some conditions of the skills assessment developed by Kodak et al. (**2015**) and conduct the skills assessment with additional participants with ASD. A modification was made to one condition in the skills assessment to reduce the likelihood that response biases influenced the assessment results. Kodak et al. reported that several participants showed an error pattern to respond to the stimulus card in the go/no-go procedure arranged in the auditory-discrimination condition. That is, instead of touching a stimulus card in the presence of one sound (e.g., a “go” response) and refraining from touching the stimulus card in the presence of a second sound (e.g., a “no-go” response), several participants in Kodak et al. consistently touched the stimulus card in the presence of both sounds. This error pattern may be common for individuals with a history of reinforcement for touching stimuli on tabletops (Bergmann et al., **2021**; Serna, **2016**; Serna et al., **2009**). The current assessment replaced the go/no-go procedure with an auditory-discrimination condition (auditory identity matching) shown to establish auditory discrimination in children with ASD by Bergmann et al. (**2021**) and included three stimuli in the array to reduce the likelihood of stimulus and position biases (Green, **2001**; Grow & LeBlanc, **2013**).

Method

Participants, Setting, and Materials

Participants included eight children or adolescents who were diagnosed with ASD by a professional not associated with this study. Refer to Table **1** for participants' ages. All participants attended a center-based intervention program and had educational or treatment goals related to acquisition of AVCD. In addition, six participants (Ryan, Ben, Roger, Hank, Doug, and Gina) had previous exposure to unsuccessful AVCD training with empirically supported practices (e.g., blocking, instruction with error correction and differential reinforcement, a simple-conditional method) in their school and center-based intervention program. Those same six participants had little to no functional vocal-verbal behavior and used a picture-based communication system to request items from others. Two participants (Lance and Arthur) communicated in full sentences and mastered most or all verbal behavior milestones measured in the VB-MAPP (Sundberg, **2008**). None of the participants had known impairments in hearing and vision (e.g., they selected preferred items from an array, they oriented toward sounds). Gina did not participate in AVCD training due to an extended absence after completion of the skills assessment.

Table 1. *Summary of Participants' Ages and Outcomes of Conditions in the Skills Assessment and Auditory–Visual Conditional Discrimination Training*

Participant	Age	IDM	Imit	VD	AD	Scan	AVCD Training
Ryan	9y, 2 m	+	+	-	-	-	-
Ben	13y, 0 m	+	+	+	-	+	-
Roger	5y, 8 m	+	+	+	-	-	-
Hank	11y, 4 m	+	+	+	-	-	-
Doug	7y, 8 m	+	+	+	-	-	-
Lance	9y, 8 m	+	+	+	+	-	+
Arthur	12 y, 9 m	+	+	+	+	-	+
Gina	8y, 8 m	+	+	+	-	-	N/A

Note. Responding that met (+) or did not meet (-) the mastery criterion during skill-assessment conditions and AVCD training. IDM = Identity-matching condition; Imit = Imitation condition; VD = Visual-discrimination condition; AD = Auditory-discrimination condition; Scan = Scanning condition; AVCD = Auditory–visual conditional discrimination.

We conducted sessions in a private room that contained a table, chairs, relevant session materials (e.g., data sheets, picture cards, BIGmack® buttons), preferred items, the participant's augmentative communication device (e.g., binder with icons), and a video camera for data collection.

The stimuli selected for inclusion in the skills assessment and AVCD training were consistent across five participants and AVCD training targets were individualized for three participants; refer to Tables 2 and 3 in the online supporting information for a list of stimuli assigned to each condition. Stimuli included in each condition were visually discrepant (e.g., different colors and shapes) and had minimal overlap in sounds (e.g., stimuli did not start nor end with the same sound; Gast, **2010**). Finally, none of the participants had prior exposure to instruction with the stimuli included in AVCD training during their behavior analytic services.

Response Measurement, Interobserver Agreement, and Procedural Integrity

The primary dependent variables in the skills assessment and AVCD training were *correct responses* and *scanning* (skills assessment only). A *correct response* was defined as touching the target stimulus in the array, depressing the target BIGmack® button in the array, or placing a picture card on top (Ryan and Doug) or in front (Ben) of the identical picture card in the array within 5 s of the initiation of the trial. *Scanning* was defined as an uninterrupted shift in the participant's eye gaze from one stimulus to the next. The experimenter converted each measure to a percentage by dividing the number of trials with an occurrence of the behavior by the total number of trials in a session, multiplied by 100.

Observers also collected data on secondary dependent variables, including *prompted responses*, *errors,* and *no responses* during trials, although these data are not displayed in the figures. A *prompted response* was defined as touching the target stimulus in the array, depressing the target BIGmack® button such that it played the auditory stimulus, or placing a picture card on top or in front of an identical stimulus in the array within 5 s of a model prompt or when physically guided. An *error* was defined as touching any stimulus other than the target stimulus in the array, depressing a BIGmack® button other than the target stimulus in the array, or placing a picture card on top or in front of a nonidentical stimulus in the array within 5 s of the initiation of the trial. A *no response* was defined as the participant failing to engage in a response to the stimuli in the array within 5 s of the initiation of the trial.

Two observers independently recorded data on each dependent variable during 60% to 100% of sessions of the skills assessment and 35% to 100% of sessions of AVCD training. The experimenter calculated agreement using a trial-by-trial method. Agreement for each trial occurred when both observers recorded the exact same dependent variable(s). Interobserver agreement was calculated by dividing the number of trials with an agreement by the total number of trials in a session and multiplying by 100. Mean agreement for all dependent variables in the skills assessment was 100% for Ryan, 93.4% (range, 67% to 100%) for Ben, 90.9% (range, 58% to 100%) for Roger, 91.8% (range, 75% to 100%) for Hank, 97.6% (range, 95% to 100%) for Doug, 98.5% for Lance (range, 91.7% to 100%), 100% for Arthur, and 99.7% for Gina (range, 97.9% to 100%). Mean agreement for AVCD training was 99.2% (range, 92%

to 100%) for Ryan, 100% for Ben, 98.4% (range, 83% to 100%) for Roger, 98.3% (range, 92% to 100%) for Hank, 99.2% (range, 92% to 100%) for Doug, 100% for Lance, and 100% for Arthur. Lower percentages in some sessions of the skills assessment were often a result of differences in scanning data.

An observer also collected data on the experimenter's procedural integrity during the 41% to 100% of skills assessment sessions and 34% to 100% of the AVCD training sessions. Procedural integrity was defined as the experimenter implementing all aspects of the protocol exactly as written during each trial (e.g., presenting the stimulus/stimuli as indicated for the trial, securing attending, waiting the allotted response interval, delivering the correct consequences). The observers scored integrity during each trial as either a 1 (all components of the trial were implemented correctly) or 0 (one or more of the trial components were not implemented correctly). The experimenter calculated the percentage of procedural integrity by dividing the number of trials with a score of 1 by the total number of trials in a session and multiplying by 100. Mean procedural integrity for the skills assessment was 98.7% (range, 96% to 100%) for Ryan, 100% for Ben, 96.7% (range, 68% to 100%) for Roger, 99.5% (range, 98% to 100%) for Hank, 99.4% (range, 97% to 100%) for Doug, 100% for Lance, 100% for Arthur, and 96.9% (range, 83.3% to 100%) for Gina. Roger's lower level of integrity occurred during the identity-matching condition in which the experimenter did not consistently say “match” prior to a response opportunity. Mean procedural integrity for AVCD training was 97.9% (range, 83% to 100%) for Ryan, 99.4% (range, 92% to 100%) for Ben, 100% for Roger, 88.3% (range, 50% to 100%) for Hank, 99.4% (range, 92% to 100%) for Doug, 100% for Lance, and 100% for Arthur. Hank's lower percentage of integrity occurred during baseline when he did not scan the array independently, and the experimenter secured attending but did not say “look” before pointing to each stimulus and providing brief praise for prompted looking.

Preference Assessment

A brief multiple stimulus without replacement (MSWO) preference assessment (Carr et al., **2000**) was conducted prior to each session. The first item selected by the participant was provided contingent on correct responses during trials. Participant mands for an alternative item during sessions (using their augmentative communication system or vocal mands) were honored.

Skills Assessment

All procedures in the skills assessment were based on those used by Kodak et al. (**2015**). In all conditions, the experimenter presented an array of three stimuli (rather than two; Kodak et al., **2015**) and stimuli were rotated across trials. This modification to the array size was made to decrease the likelihood of establishing a position bias (Green, **2001**) and to align the array size with current AVCD practice recommendations (e.g., Grow & LeBlanc, **2013**; LaMarca & LaMarca, **2018**). Representative pictures of the stimulus arrangement in each condition are available in Supporting Information.

All conditions included 12 trials per session. Two to six sessions were conducted per day, 3 to 5 days per week. A multielement design was used to evaluate the effects of each condition in the skills assessment on correct responses. The conditions included identity matching, imitation, visual discrimination, auditory discrimination, and scanning. Skills assessment conditions alternated in a semirandom order; we conducted the same condition no more than two sessions in a row. The mastery criterion for each condition in the skills assessment was two consecutive sessions with at least 80% correct responses. Once the participant's responding reached mastery in one condition in the skills assessment, sessions of the remaining conditions continued in semirandom alternation until either every condition was mastered or a condition reached the 10-session discontinuation criterion (Kodak et al., **2015**).

During trials, the experimenter placed three picture cards or four BIGmack® buttons on the table in front of the participant. The location of the target stimulus in the array was randomly rotated during each trial so that target stimuli were placed in each position in the array an equal number of times per session.

Identity Matching

The experimenter placed three pictures in a horizontal array in front of the participant, either handed the participant a picture card (Ryan, Ben, and Doug) or held up a picture card (Roger, Hank, Lance, Arthur, and Gina), and said “match.” If the participant placed the picture card on top (Ryan and Doug) or in front (Ben) of the corresponding picture in the array, or if the participant touched the corresponding picture in the array (Roger, Hank, Lance, Arthur, and Gina), the experimenter provided enthusiastic praise and an edible or 20-s access to a tangible item. Following an error or no response within 5 s, the experimenter cleared the array and presented the next trial. Scanning was measured during each trial.

Imitation

The experimenter placed three pictures in a horizontal array on the table in front of the participant and said “do this” while pointing at one of the pictures. If the participant imitated the experimenter's behavior by pointing to the same picture in the array, the experimenter provided enthusiastic praise and an edible or 20-s access to a tangible item. If the participant pointed to a different picture or did not respond within 5 s, the experimenter cleared the array and moved to the next trial. The target picture and location in the array changed across trials.

Visual Discrimination

The experimenter placed three pictures on the table in front of the participant. One picture served as the target stimulus in all trials in each session (e.g., a horse), and the array remained constant (i.e., the same three pictures were presented in every trial although the position rotated across trials). The first session included a 0-s prompt delay in which the experimenter immediately provided a model prompt or physically guided (Ryan only) the participant to touch the target stimulus. Correct prompted responses produced enthusiastic praise and an edible or 20-s access to a tangible item. The purpose of the 0-s delay session was to provide exposure to the contingency for correct responses to the target stimulus. The remaining sessions of this condition did not include prompts. The participant had up to 5 s to respond to the target stimulus in the array. Correct responses produced praise and an edible or 20-s access to a tangible item, and an error or no response within 5 s resulted in removal of the array and the end of the trial.

Auditory Discrimination

Due to a bias that some participants showed to touching a blank white card placed on the table in every trial regardless of the auditory stimulus presented, the procedures for this condition were modified from those of Kodak et al. (**2015**). Instead of measuring a go/no-go auditory discrimination (i.e., touching a blank white card in the presence of sound A [go trials] and refraining from touching a blank white card in the presence of sound B [no-go trials]), the auditory discrimination assessed in this condition was auditory–auditory matching (Bergmann et al., 2021).

One auditory stimulus served as a target in each trial, although three auditory stimuli rotated as the target stimulus across trials. The array remained constant (i.e., the same three auditory stimuli were presented in every trial) although the locations of buttons rotated across trials. The experimenter placed one BIGmack® button in front of herself (i.e., the sample stimulus) and three BIGmack® buttons in a horizontal array in front of the participant (i.e., the comparison array). The experimenter pressed her button to play the auditory sample stimulus. Immediately thereafter, the experimenter pressed each button in the array from left to right, allowing the auditory stimulus to finish playing before pressing the next button in the array. The experimenter said "match" and then activated the sample stimulus again. The first session of this condition included a 0-s prompt delay in which the experimenter immediately provided a model prompt (Doug only) or physically guided the participant to press the button in the array that played the auditory stimulus that matched the sample and delivered enthusiastic praise and an edible or 20-s access to a tangible item following correct prompted responses. During all remaining sessions, the experimenter did not provide prompts, and the participant had 5 s to engage in the correct response. Contingent on a correct response, the experimenter provided enthusiastic praise and an edible or 20-s access to a tangible item. An error or no response within 5 s resulted in removal of the array and the end of the trial.

Scanning

Data on scanning were consistent across identity-matching and imitation conditions in Kodak et al. (**2015**). Therefore, observers collected data on scanning during sessions of the identity-matching condition only to increase the feasibility of this measure for data collectors. No praise, edibles, nor preferred items were provided contingent on scanning.

AVCD Training

Training began after the completion of the skills assessment. The current AVCD training differed from the procedures used by Kodak et al. (**2015**) who exposed participants to sequential or alternating training procedures (e.g., differential reinforcement without prompts, position prompts, model prompts). We selected a prompt-delay procedure during training, because prompt delays in prior studies produced mastery level responding for some participants with ASD who had difficulty acquiring AVCDs (Grow et al., **2011**) or verbal conditional discriminations (Kisamore et al., **2016**).

A nonconcurrent multiple baseline across participants design was used to evaluate the effects of intervention on correct responses during AVCD training. Training continued until the participant's responding met the mastery criterion of two consecutive sessions with at least 80% correct responses or the training discontinuation criterion was reached. To prevent extended exposure to ineffective training procedures, if the participant's responding did not reach the mastery criterion or show an increasing trend following 15 sessions of training (not including two sessions conducted at 0-s prompt delay), the experimenter discontinued training. If an increasing trend in correct responding was observed after 15 training sessions (Ben only), then the experimenter conducted an additional 15 sessions of training (30 sessions total) before discontinuing training. The experimenters selected a 15-session discontinuation criterion for training based on outcomes of the duration of AVCD training in Kodak et al. (**2015**) and a similar criterion used by Kisamore et al. (**2016**).

Sessions included 12 trials. During all trials, the experimenter placed three picture cards in a horizontal array in front of the participant. The experimenter required the participant to look at each stimulus in the array (either independently or following a prompt to "look" while pointing at each stimulus), and delivered the auditory sample stimulus (e.g., "shell"). That is, participants were required to scan the array prior to the presentation of the auditory sample stimulus and an opportunity to select a comparison stimulus. The participant had up to 5 s to engage in a response after the delivery of the auditory sample stimulus.

Baseline

If the participant engaged in a correct response, the experimenter provided enthusiastic praise only (except Arthur). Because reinforcers were omitted for correct responses in baseline, Arthur did not receive enthusiastic praise following correct responses due to praise functioning as a reinforcer. An error or no response within 5 s resulted in the removal of the array and end of the trial. Mastered tasks were interspersed approximately every three trials to maintain participant responding (Bergmann et al., **2021**; Halbur et al., **2021**). Correct responses to mastered tasks produced enthusiastic praise and an edible or 20-s access to a tangible item. An error or no response to mastered tasks resulted in a prompt and the presentation of a different mastered task to which a correct response produced reinforcement.

Training

The procedures were similar to baseline, except mastered tasks were not interspersed during training, and prompts and reinforcement were included in trials. The first two sessions of training included a 0-s delay to a prompt (data not included in the figures). The experimenter presented the auditory sample stimulus and immediately provided a model prompt. If a prompted response occurred within 5 s of the prompt, the experimenter delivered enthusiastic praise and an edible or 20-s access to a tangible item. Thereafter, the experimenter implemented a 5-s prompt delay in which the participant had 5 s to engage in a correct response. Following an error or no response within 5 s, the experimenter repeated the conditional stimulus and provided a model prompt and provided praise and an edible or 20-s access to a tangible item following a prompted response. If the participant did not engage in a prompted response following the model prompt, the experimenter provided physical guidance and delivered praise only. Training continued until correct responding met the mastery criterion or reached the discontinuation criterion (i.e., 15 sessions of training with the 5-s prompt delay with no increasing trend in correct responding).

Results

Results of the skills assessment for all eight participants are displayed in Figures **1**-**3** and Table **1**. Ryan met the mastery criterion in the identity-matching and imitation conditions (Figure **1**, top panel). Ryan's percentage of trials with scanning during the identity-matching condition was relatively low; nevertheless, his correct responses during identity matching sessions suggest that he was attending to the visual stimuli in a sufficient manner. Data collection on scanning was discontinued prior to reaching the mastery criterion, because the identity-matching condition was no longer conducted following mastery. Ryan's responding met the discontinuation criterion in the visual-discrimination and auditory-discrimination conditions.

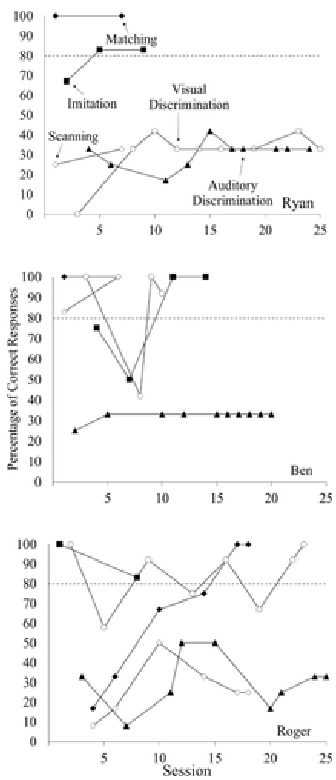

Figure 1 *Results of the Skills Assessment for Ryan, Ben, and Roger*
Note. The dotted line represents the percentage required for mastery.

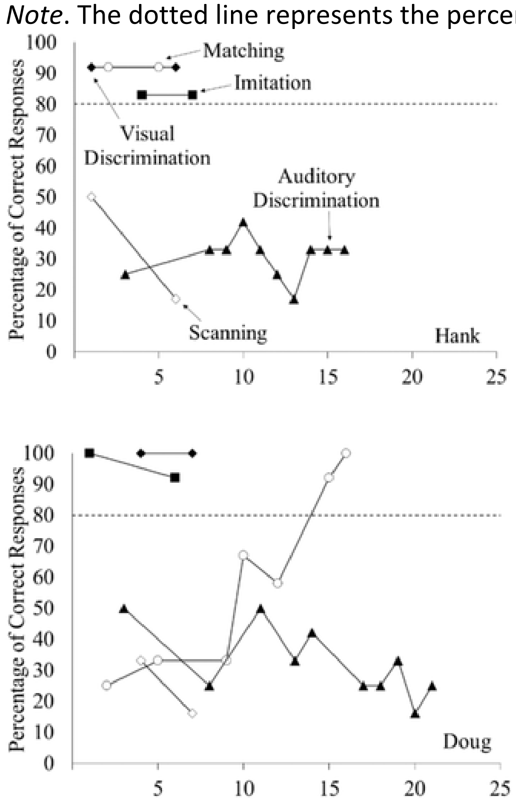

Figure 2 *Results of the Skills Assessment for Hank and Doug*
Note. The dotted line represents the percentage required for mastery.

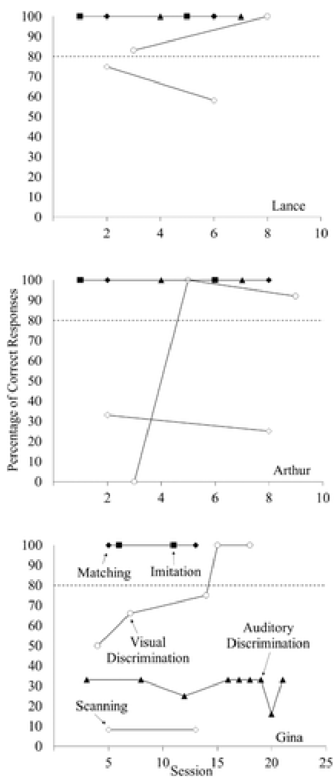

Figure 3 *Results of the Skills Assessment for Lance, Arthur, and Gina*
Note. The dotted line represents the percentage required for mastery.

Ben's responding met the mastery criterion in the identity-matching, scanning, visual-discrimination, and imitation conditions (Figure **1**, middle panel). However, his responding met the discontinuation criterion in the auditory-discrimination condition.

Roger's responding met the mastery criterion in the imitation, identity-matching, and visual-discrimination conditions (Figure **1**, bottom panel). Similar to Ryan, Roger also had low and variable levels of scanning during identity matching, and data collection was discontinued following mastery of identity matching. Roger's responding met the discontinuation criterion in the auditory-discrimination condition.

Hank's responding met the mastery criterion in the visual-discrimination, identity-matching, and imitation conditions in the minimum number of sessions (Figure **2**, top panel). However, similar to Ryan and Roger, Hank displayed low levels of scanning during identity matching, and data collection on scanning was discontinued following mastery of identity matching. Hank's responding met the discontinuation criterion in the auditory-discrimination condition.

Doug's responding met the mastery criterion in imitation, identity-matching, and visual-discrimination conditions (Figure **2**, bottom panel). However, he also had low levels of scanning behavior during identity matching, and data collection on scanning was discontinued following mastery of identity matching. Doug's correct responding was variable and met the discontinuation criterion in the auditory-discrimination condition.

Lance's responding met the mastery criterion in imitation, identity-matching, and visual-discrimination, and auditory-discrimination conditions (Figure **3**, top panel). However, he also had low levels of scanning behavior during identity matching, and data collection on scanning was discontinued following mastery of identity matching.

Arthur's responding met the mastery criterion in imitation, identity-matching, visual-discrimination, and auditory-discrimination conditions (Figure **3**, middle panel). Similar to Doug and Lance, Arthur had low levels of scanning behavior during identity matching, and data collection on scanning was discontinued following mastery of identity matching.

Gina's responding met the mastery criterion in imitation, identity-matching, and visual-discrimination conditions (Figure **3**, bottom panel). Similar to other participants, she had low levels of scanning behavior during identity matching, and data collection on scanning was discontinued following mastery of identity matching. Gina's correct responding was low and met the discontinuation criterion in the auditory-discrimination condition.

Overall, the skills assessment showed that none of the eight participants demonstrated mastery of all five conditions. However, two participants (Lance and Arthur) met mastery in all conditions except scanning. Four of the participants' responding failed to meet the mastery criterion in at least two conditions (Ryan, Roger, Hank, and Doug), and six of the participants did not display mastery level responding in the auditory-discrimination condition.

The results of AVCD training for Ryan, Ben, and Roger are shown in Figure **4** and Table **1**. Ryan's correct responding during baseline was low and at chance level (e.g., 33%; Figure **4**, top panel). His responding remained low and variable despite the introduction of training, and he met the discontinuation criterion after 15 sessions without an increasing trend. Ben's correct responses in baseline were stable and at chance level (Figure **4**, middle panel). Ben displayed a bias toward the middle position in the stimulus array. Following 15 sessions of training, Ben's correct responses showed a gradual increasing trend. Therefore, we continued training for an additional 15 sessions (i.e., 30 sessions total). However, his correct responses stabilized and did not meet the mastery criterion. Roger's correct responses were low and variable in baseline (Figure **4**, bottom panel) and following the introduction of training. Roger's responding met the discontinuation criterion.

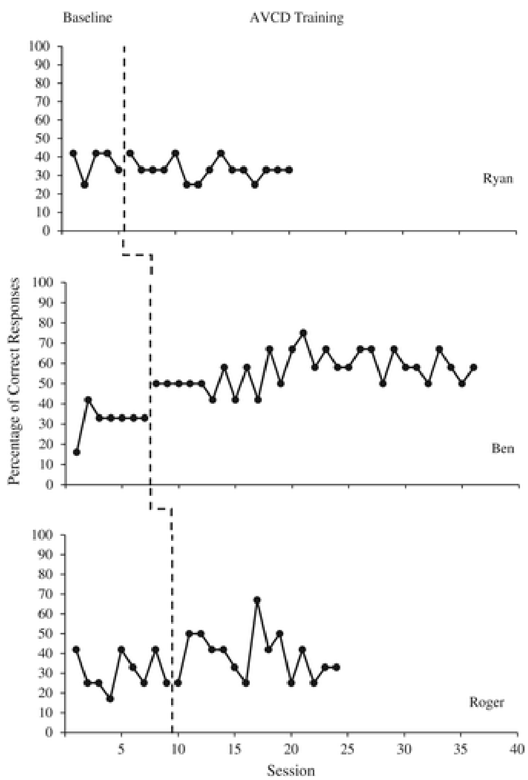

Figure 4 *Auditory–Visual Conditional Discrimination (AVCD) Training for Ryan, Ben, and Roger*

The results of AVCD training for Hank and Doug are shown in Figure **5** and Table **1**. Hank's correct responses were low and at chance level during baseline (Figure **5**, top panel) and training. Hank's responding met the discontinuation criterion. Doug had low and variable levels of correct responses during baseline (Figure **5**, bottom panel). Although he showed an increase in correct responding in the first session of training, Doug's correct responses decreased and remained at chance level until training was discontinued.

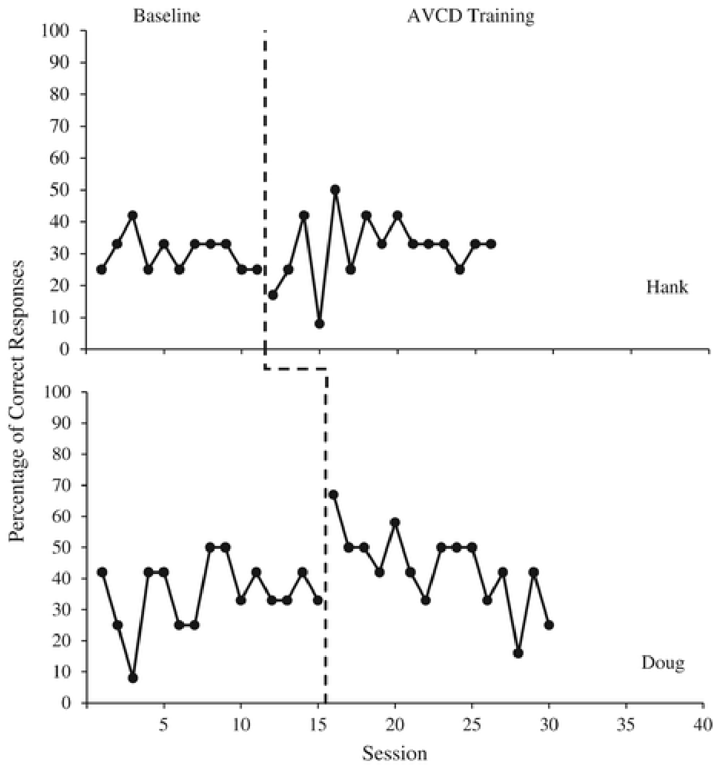

Figure 5 *Auditory–Visual Conditional Discrimination (AVCD) Training for Hank and Doug*

The results of AVCD training for Lance and Arthur are shown in Figure **6** and Table **1**. Lance's correct responses increased from zero in baseline to mastery level in just two training sessions following the 0-s prompt delay (0-s prompt delay data not shown in figure). Similarly, Arthur's correct responses also reached mastery level following two sessions of training.

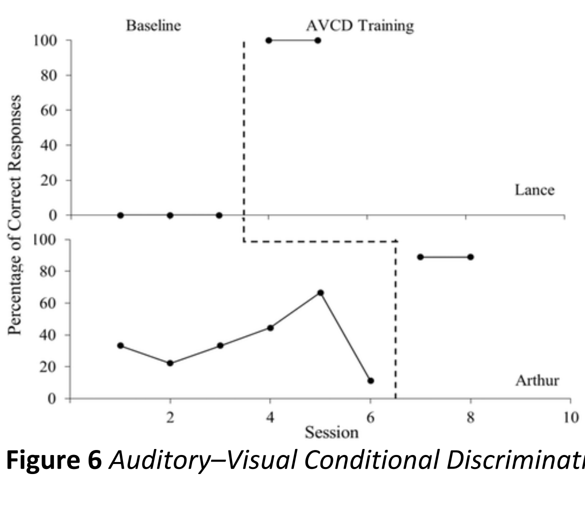

Figure 6 *Auditory–Visual Conditional Discrimination (AVCD) Training for Lance and Arthur*

Overall, the results of AVCD training showed only two of the seven participants (Lance and Arthur) demonstrated mastery of three AVCD targets despite 15 or 30 (Ben only) sessions of training. The training results of two participants (Lance and Arthur) were not accurately predicted by the outcome of their skills assessments, because those participants did not engage in mastery level responding in the scanning condition of the skills assessment. In contrast, the training results of five participants (Ryan, Ben, Roger, Hank, and Doug) were accurately predicted by the outcomes of the participants' skills assessments, which suggested that those five participants were missing one or more skills that may be necessary for successful AVCD training.

Discussion

The results of the skills assessment accurately predicted the outcome of AVCD training for five of the seven participants. In particular, the skills assessment was most accurate in predicting participants who would not benefit from AVCD training. All five participants whose responding failed to meet mastery during AVCD training also had responding that failed to meet mastery in one or more of the conditions in the skills assessment. For the two participants whose responding met mastery during AVCD training (Lance and Arthur), their skills assessment showed mastery of all conditions except scanning. If data on scanning are removed from the analysis, then the skills assessment accurately predicted the outcome of AVCD training for all seven participants.

The predictive utility of the skills assessment in the present study partially replicates the results of Kodak et al. (**2015**) in regard to the auditory-discrimination condition being a particularly accurate predictor of success with AVCD training. Five participants in Kodak et al. and two participants in the present investigation who demonstrated mastery in the auditory-discrimination condition also demonstrated mastery during AVCD training. Further, two participants in Kodak et al. and five participants in the current investigation who did not demonstrate mastery in the auditory-discrimination condition in the skills assessment also failed to demonstrate mastery during AVCD training. In sum, the results of the auditory-discrimination condition alone accurately predicted AVCD training outcomes for 14 of 17 participants across both studies.

The results of the auditory-discrimination condition are consistent with other measures of auditory discrimination (e.g., echoics, instruction following) that were conducted with participants prior to both studies and showed deficits in this repertoire. For example, five of the participants in the current study (Ryan, Ben, Roger, Hank, and Doug) and three of the participants in Kodak et al. **2015** (Hal, Larry, and Freddy) did not engage in echoic behavior and most showed limited success and faulty stimulus control during programs targeting auditory instruction following (e.g., "come here"). In contrast, three of the participants in the current study (Lance, Arthur, and Gina) and six participants in Kodak et al. (Rose, Linda, Brandan, Wyatt, Josh, and Amar) engaged in echoic behavior and followed one-step instructions. Auditory discrimination and echoic behavior, in particular, may be crucial for successful AVCD training due to the necessity of joint control. Lowenkron (**1998**) described joint control as "… a discrete event, a change in stimulus control that occurs when a response topography, evoked by one stimulus and preserved by rehearsal, is emitted under the additional control of a second stimulus" (p. 332). For example, a learner likely needs to echo the auditory sample stimulus (e.g., repeat "cat" covertly or overtly immediately after the instructor says, "cat") and engage in self-echoic behavior (e.g., continue repeating "cat" overtly or covertly). The self-echoic behavior preserves the auditory sample stimulus through rehearsal while simultaneously scanning the array of visual stimuli. When the learner sees the picture of the cat in the array and (overtly or covertly) tacts the picture as "cat," the auditory product of the tact matches the auditory product of the self-echoic behavior and occasions a pointing response to the picture of the cat (Miguel, **2016**; Striefel et al., **1976**). If a learner cannot yet echo auditory stimuli (as was the case for many participants in the current study and several in Kodak et al., **2015**), then the transient nature of the auditory stimulus without rehearsal may decrease accuracy during AVCD training. Although it may be possible to replace the auditory-discrimination condition in the skills assessment with an assessment of echoic behavior (e.g., EESA; Esch, **2008**), a nonvocal assessment of auditory discrimination may be a more inclusive measure for all individuals with potential impairments in skills related to AVCD.

The current study modified the procedures in the auditory-discrimination condition from those used by Kodak et al. (**2015**) to reduce the likelihood of biased responding. Some participants in Kodak et al. engaged in biased responding during a go/no-go procedure by consistently touching the blank white card on the table during all trials rather than only touching the card in the presence of the relevant auditory stimulus. Other researchers also have reported biased responding for individuals with developmental disabilities exposed to the go/no-go procedure (e.g., Bergmann et al., **2021**; Serna, **2016**; Serna et al., **2009**). The current modification arranged an auditory match-to-sample procedure in which participants matched identical auditory stimuli. This procedure was based on Speckman-Collins et al. (**2007**) and Bergmann et al. (**2021**) who taught auditory discriminations using auditory match-to-sample procedures to children with ASD. In addition, this procedure is akin to an auditory match-to-sample task included in the Headsprout® reading program, which has been used successfully with learners with ASD (e.g., Grindle et al., **2013**; Plavnik et al., **2016**). Nevertheless, the complexity of the auditory match-to-sample discrimination may prevent assessment of an auditory-discrimination repertoire for learners who could respond appropriately to less complex auditory-discrimination procedures (Serna, **2016**). Researchers seeking to evaluate alternative auditory-discrimination procedures (e.g., EESA; Esch, **2008**; do this/do that; Bergmann et al., **2021**) to include in the skills assessment could compare levels of correct responses across procedures to determine if one method may be ideal for most learners. However, we recommend that any comparison of auditory-discrimination procedures for this skills assessment include an evaluation of performance during AVCD training to examine the correlation of assessment and treatment outcomes.

Unlike most of the participants in Kodak et al. (**2015**), six of the current participants had already received extended exposure to unsuccessful AVCD training at school and during their behavioral intervention prior to completion of the skills assessment. Extended exposure to a variety of instructional strategies that fail to establish AVCD may be common for a proportion of children with ASD, due to the ubiquity of this type of training in educational settings (Grow & LeBlanc, **2013**; Kodak et al., **2018**). Learners who have educational goals related to AVCD but do not have relevant repertoires upon which to establish these skills may develop error patterns during training such as response or position biases (Grow et al., **2011**; Saunders & Spradlin, **1989**; **1990**; **1993**) that can complicate or hinder subsequent instruction. Participants in the present study displayed some of these error patterns during the skills assessment and AVCD training. For example, the five participants whose responding did not reach mastery during AVCD training showed a position bias in baseline and treatment during AVCD training. Ryan, Ben, Hank, Doug, and Gina also responded to a specific position in the array more often during the auditory-discrimination condition of the skills assessment, and Ryan had a similar bias during a portion of sessions in the visual-discrimination condition.

Consistent error patterns may occur during instruction because it maximizes reinforcement for chance-level responding when the skill has not yet been acquired (Cumming & Berryman, **1961**; Kangas &

Branch, **2008**; Mackay, **1991**). For example, responding to the left position on every trial, in an array of three, produces reinforcement during approximately 33% of trials, whereas random responding across positions may result in more variable (and sometimes leaner) schedules of reinforcement. It is possible that persistent error patterns suggest that other, related skills (such as those included in the skills assessment) could be taught or strengthened rather than continuing instruction on the current skill (e.g., AVCD). Additional research is needed to evaluate whether certain response patterns suggest deficits in a skill area that, once resolved, might lead to successful learning.

There are several limitations of the current study that warrant consideration. The experimenters discontinued AVCD training following 15 or 30 treatment sessions (plus two, 0-s prompt delay sessions not included in the figure nor discontinuation criterion). It is possible that responding may have eventually met the mastery criterion following extended training. However, results of Kodak et al. (**2015**) show that participants' responding reached mastery criterion in 2 to 11 training sessions, and participants who required 12 or more sessions of instruction (maximum of 18 sessions) did not show increasing levels of correct responses nor have responding that reached the mastery criterion. In addition, other researchers have used a similar discontinuation criterion for conditional discrimination training with a constant-prompt delay (e.g., Kisamore et al., **2016**). Our participants were exposed to 60 trials of instruction per stimulus with no increasing trend in correct responses before training was discontinued, whereas Kisamore et al. (**2016**) determined that 50 trials of verbal conditional discrimination training per stimulus with no increasing trend indicated the training procedure was ineffective and necessitated remedial training.

We could have made modifications to AVCD training (e.g., blocking; Saunders & Spradlin, **1989**) which may have resulted in the mastery of AVCD training. However, we replicated an empirically validated training procedure included in Kodak et al. (**2015**) rather than making additional modifications. Further, we determined that lengthy exposure to training was not clinically indicated for most of the participants because they had already been exposed to several training procedures (e.g., prompt delays with error correction, identity-matching prompts, extensive simple discrimination training, blocking) during unsuccessful instruction on AVCD prior to participation. Further, our clinical goals for most of these participants was to identify skills that were not mastered in the skills assessment that would become the focus of subsequent instruction. Future evaluations of the skills assessment could arrange a sequence of instructional strategies during AVCD training (e.g., Grow et al., **2011**) to attempt to produce mastery of targeted conditional discriminations.

Similar to Kodak et al. (**2015**), the current findings suggest that the definition of scanning may be too stringent and could be revised or excluded. Several of our participants engaged in high levels of correct matching that were contrary to the low levels of scanning measured within the same trials. Rather than engaging in an uninterrupted eye-gaze shift from one stimulus to the next in the array (i.e., our definition of scanning), participants could have looked at each stimulus after brief instances of looking elsewhere (e.g., Lance and Bryce). Observers did not score an instance of scanning if participants shifted their gaze from a comparison stimulus back to the sample stimulus. Although interruptions in scanning may increase the length of time necessary to attend to the array, an efficient scanning response does not appear to be necessary for successful visual identity matching. Researchers who seek to evaluate components of the skills assessment could modify the definition of scanning to allow for interruptions in eye-gaze shift. One may also consider whether it's necessary to scan all stimuli in the array if the participants' eye gaze is directed toward the correct stimulus. Anecdotally, the experimenter observed that Arthur frequently scanned the array until he reached the correct comparison stimulus, and then he stopped scanning. If the correct comparison was in the left or middle position in the array, correct scanning was not scored because Arthur did not scan the entire array of comparisons. Nevertheless, we do not recommend omitting a measure of scanning or eye gaze altogether, as persistent patterns of responding without looking at stimuli would likely invalidate the results of the skills assessment.

Finally, the necessity of the skills assessment versus measurement of these skills via other assessments remains unknown. For example, identity matching, imitation, visual discrimination, and some types of auditory discrimination (echoics, instruction following) are measured in the VB-MAPP. Researchers could examine whether measures of these skills in the VB-MAPP are similarly or more accurate than the predictive validity of the current skill assessment for success during AVCD training. If specific skills measured in the VB-MAPP could be used to accurately predict whether and when to initiate AVCD training with learners, practitioners will benefit from instruction on the use of the VB-MAPP results for this purpose.

Currently, the skills assessment can only be used as a predictive tool to identify learners who may not benefit from AVCD training. However, an important next step for the assessment is to determine whether there is a functional relationship between the skills measured in the assessment and acquisition of AVCDs. To do so, researchers will need to (1) conduct the skills assessment and identify learners who do not show mastery of one or more skills, (2) conduct AVCD training with a set of stimuli that does not lead to mastery level responding, (3) teach the missing skills from the assessment (this step may include substeps), and (4) repeat AVCD training with the same set of stimuli to determine whether mastery of the previously missing skills subsequently leads to acquisition of AVCD. Due to the length of time required to complete the proposed steps, it will be critical to include a control group of participants who complete the initial skills assessment and fail to acquire AVCDs during training and then repeat AVCD training after a similar length of time but who *do not* receive instruction on missing skills. Arranging the proposed comparison will evaluate the necessity and sufficiency of the skills measured in the skills assessment for successful AVCD training. Although it is unethical to restrict learning opportunities for clients to conduct the proposed comparison, children with ASD who do not receive intervention services that target the skills included in the assessment can serve as control participants for an initial evaluation of this question.

Despite the prevalence of AVCD in our environment and educational opportunities, children with ASD require behavioral intervention to acquire AVCD. Nevertheless, a proportion of children with ASD who are exposed to empirically validated interventions may fail to acquire this critical repertoire. Rather than exposing them to extended instruction with multiple procedures that do not produce the intended outcomes, behavior analysts must identify and consider skills that relate to targeted intervention goals. The development of relevant skills assessments for repertoires that may be difficult to establish with certain learners can enhance the success of practitioners and advance the science of behavior analysis. Continued research and refinement of the skills assessment in the present investigation will assist in identifying the relevant skills that are necessary and sufficient for success during AVCD training.

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