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A NOVEL METHOD FOR TEACHING THE FIRST INSTANCES OF SIMPLE DISCRIMINATION TO NONVERBAL CHILDREN WITH AUTISM IN A LABORATORY ENVIRONMENT

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Abstract

A novel method for initiating discrimination training with nonverbal children combines a delayed S + procedure that requires children to refrain from responding to either of 2 physically different choice stimuli until a prompt stimulus is added onto 1 of the choices, and a delayed prompting procedure that presents the same 2-choice stimulus display, but stimuli are initially added onto both choices. After a short delay, the added stimulus on the S- is removed, and the choice of the S+ is thus prompted. If the children learn to observe and respond to the defining features of the S+ choice stimulus, then they may respond to the S+ prior to the added-stimulus removal. Implementation was successful with 8 nonverbal children who had not previously exhibited simple simultaneous discrimination, suggesting a useful methodology for initiating discrimination training with populations for whom verbal instruction is ineffective.

Among the most difficult challenges for behavioral scientists and educators is to communicate effectively with children who are nonverbal (Sidman & Stoddard, 1966). The challenge is similar to that faced in interspecies communication, for example, when humans endeavor to teach new behavior to nonhuman primates (e.g., Barros, Galvão, & McIlvane, 2002).

Communicating with nonverbal children, however, has additional complexities that increase the challenge. For example, in behavioral research with children, one does not make use of establishing operations such as food deprivation. Even seemingly benign procedures such as simple differential reinforcement (“trial-and-error” training) may have negative effects that argue against their use: emotional responses associated with errors and inadvertent creation of error patterns that may preclude acquisition of seemingly elementary discrimination performances (e.g., Stoddard & Sidman, 1967). As a consequence, little is known scientifically about the discrimination learning potential of nonverbal children under true laboratory conditions.

Laboratory conditions are desirable, of course, because it is difficult otherwise to isolate variables that influence behavior. In human-administered discrimination tasks, the possibility of inadvertent examiner cuing has been recognized for decades, even in the case in which

participants are nonhumans. Indeed, one consideration that led to the development of the Wisconsin General Test Apparatus for nonhuman primates (Harlow, 1949) was the need to control cues in the experimenter's behavior (e.g., direction of gaze, body position, reactions to incipient behavior). These methodological considerations seem no less pertinent when research participants are humans, although the logistical challenges in addressing them comprehensively are more daunting.

Within the experimental analysis of behavior, there have been few examples of efforts to study human behavior under the conditions of rigor that are routinely employed with nonhuman participants. Perhaps the best known are NASA-supported studies of behavior in environments that model conditions of interplanetary space travel (Brady, 1992). In clinical research, such work was pioneered by Ferster and colleagues with children with autism (e.g., Ferster & DeMeyer, 1961). The most comprehensive effort thus far, however, was conducted by Stoddard and his colleagues (McIlvane & Stoddard, 1981; Stoddard, 1982; Stoddard & Gerovac, 1981).

One objective of Stoddard's program was to create a benign laboratory environment that would allow control of social variables and rigorous study of a range of clinically important topics related to severe intellectual disability. Such problems included management of chronic aberrant behavior (Stoddard, 1982), development of reliable stimulus control by means of visual and auditory events (e.g., McIlvane, Kledaras, Dube, & Stoddard, 1989; Stoddard & McIlvane, 1989), and formation of learning sets and stimulus classes (e.g., McIlvane & Stoddard, 1985). Regrettably, this promising program was suspended in the mid-1990s owing to logistical issues and to Stoddard's untimely death.

Some years ago, we had an opportunity to revive the Stoddard program and to focus its efforts specifically on children with autism spectrum disorders and related disabilities. A new automated learning environment was created within a residential school that provided access to a large population of such children, many of whom were nonverbal (i.e., having no or virtually no functional communication skills). Our challenge, addressed but not solved in earlier work by the Stoddard group, was to develop reliable methodology for initiating discrimination training and for motivating these children to sustain their participation in long-term training studies.

For initial study we chose simple simultaneous discrimination of food items, a task with multiple advantages from the perspective of both theory (e.g., McIlvane & Dube, 2003) and experience (e.g., McIlvane & Stoddard, 1981). Concerning the theoretical advantages, favorite food items are highly salient stimuli that are likely to control effective observing behavior by children. Further, if children are permitted to consume the food items after selecting them, that procedure arranges temporally immediate, multidimensional feedback in the course of reinforcement operations. Among the practical advantages, such foods maintain potency as reinforcers without use of establishing operations deemed unacceptable for our work.

The primary challenge in teaching discrimination is to direct the child's behavior to the stimulus features that differentiate S+ from S-. When discriminative stimuli are two preferred food items, one must overcome tendencies to respond to both. Simple differential reinforcement (trial-and-error) techniques are available, of course, but they have the negative characteristics mentioned earlier. Our challenge, therefore, has been to develop efficient, effective, practical methods for prompting new behavior for children who do not understand verbal instructions. This effort has proven to be highly time- and labor-intensive (McIlvane et al., 1989).

The present study represents a systematic extension of earlier work. We developed a variant of the "delayed cue" procedure first reported by Touchette (1971) and further developed by Sidman (1977). In the Sidman variant, S+ and S- stimuli are displayed, with the latter only

briefly present at trial onset (at first for a time period shorter than the participant's typical latency). Removal of the S− thus prompts selection of the remaining S+. Over trials, the S− is exposed for progressively longer durations, giving the participant the opportunity to exhibit mastery of the S+ versus S− discrimination. If errors occur, the S− exposure time is decreased to forestall further errors and to repeat program steps that may lead to mastery.

In the food-item discrimination tasks that we sought to teach, physical removal of the S− could not be effected as rapidly as in Sidman's (1977) work. Our stimuli were presented in transparent compartments via two rotating divided, tricompartiment disks (similar to lazy Susan trays). To substitute for physical S− removal, we lit both compartments at trial onset and then extinguished illumination in the S− compartment: to prompt S+ selections. Because the food items remained visible, however, stimulus control by relative compartment illumination had to be achieved (i.e., selection of the food visible within the S− compartment had to be discouraged). We pursued this teaching goal via what has been termed the “delayed S+” procedure by McIlvane, Kledaras, Callahan, and Dube (2002). In this procedure, both the S+ and S− stimuli are presented simultaneously. If no responses are made to them within a short delay period, the S+ is cued; responses prior to cuing further delay the S+ cue—hence the “delayed S+” nomenclature.

On their face, the procedural requirements of the delayed S+ and delayed cue procedures seem at odds or even incompatible with each other. Nevertheless, combined use of the two procedures in the current study proved surprisingly efficient and effective in comparison with past efforts (McIlvane et al., 1989, 2002). Summarizing briefly the aims and findings of the earlier studies, a substantial cohort of nonverbal persons received extensive training with the goal of establishing a red light or other stimulus as an effective cue for S+ selections. After varying and often substantial amounts of trial-and-error training, accuracies sometimes exceeded chance levels but never reached consistent, high levels. After subsequent training with delayed S+ procedures, however, these participants were able to discriminate the cuing stimulus with high accuracy.

In the current study, training began with the delayed S+ procedure from the outset. Then participants were switched to the delayed cue procedure. There were two questions of primary interest: (1) How rapidly would the delayed S+ procedure isolate relevant stimulus differences: light versus no-light stimulus differences? (2) How effectively would these differences function as prompts in a delayed cue procedure? We report our findings in part to describe effective methodology for initiating discrimination training with nonverbal children and in part because our counterintuitive findings may lend some support to certain aspects of recent theoretical analyses of stimulus control processes in discrimination learning.

Method

Participants

The participants were 8 students at a private residential school in the northeastern United States. Age, diagnosis, and language-age equivalence information are listed in Table 1. All of the children were nonverbal. Autism diagnoses were obtained from student records. Four children had no prior experimental history (BYI, KVR, SBA, and TNT). The remaining four had participated in unrelated studies (AXB, BAO, JGR, and NAS). Each of them had undergone a brief teaching assessment that established tracking through touching of a single form stimulus that was presented in various locations on a touch screen-equipped computer monitor. Subsequently, efforts were made to establish S+ versus S− form discriminations, but none were successful. Experimental sessions lasted 15 to 30 minutes and were conducted two to three times per week in an automated teaching laboratory (ATL) in the children's school building.

Apparatus and Stimuli

All sessions took place in the ATL, which was entirely contained within a completely divided 3.6 m × 3.6 m room. Because details of the laboratory have been described comprehensively elsewhere (Lionello-DeNolf & McIlvane, 2003), only aspects relevant to the current study will be described here. In the teaching area, the participant was seated alone in front of a stimulus panel. The panel contained two compartments with clear, sliding doors that could be locked or unlocked by the researcher via an electromechanical interface. The compartments could be lit with white light and contained the aforementioned tricompartiment disks such that items could be rotated in and out of view. Beneath these compartments were two others (wells) that did not have doors. They were used to deliver food-item reinforcers for some participants when tokens were inserted into a slot positioned to the immediate left of the compartments with doors.

On the researcher's side of the apparatus, the compartments could be accessed to insert and remove stimuli on a trial-by-trial basis. Experimental operations were controlled by a Lab View software program (National Instruments, Inc.) running on a Macintosh G4 computer. Two researchers conducted each session. One researcher entered commands into the controlling computer and recorded the participants' responses. The other loaded and unloaded the compartments and, in some cases, delivered reinforcers into the food wells (see below). The participant could be viewed at all times by means of closed-circuit television.

To avoid unwanted initial competition by food preference, it was necessary to identify food items that could be discriminated on other physical bases (e.g., color, for example, M&Ms candy). Food items for an initial reinforcer assessment were based on recommendations from our participants' teachers. For some participants, food preferences were unstable (cf. Egel, 1981) or were inappropriate choices for other reasons. In such cases, different-colored tokens (pokerchips.com) were used. For five participants (AXB, KVR, JGR, NAS, and SBA), stimuli used in training consisted of food items that were available in at least two easily discriminable colors; for BYI, TNT, and BAO, different-colored tokens were used.

Procedure

Preliminary training—In the first session, participants were allowed to explore the novel ATL environment and become accustomed to it. Preferred food items were placed along the counter and inside the food wells. The participant was left alone in the teaching area and given several minutes to consume the foods. Then the experimenters turned the lights on in the food wells (alternating irregularly from right to left) and delivered foods for 6–10 trials. The second session proceeded in much the same manner except that the food items were presented only in the two upper compartments with the doors opened. When the participant retrieved the food, the experimenter manually closed the door from the programming area. Once all of the food was consumed, compartment training began.

Compartment training—In these sessions, the participants were taught to open and close the compartment doors to obtain foods. At the beginning of a trial, all compartments were dark and their doors were closed. A single food item was placed in one compartment (determined with a prearranged random sequence), and both compartments were rotated out such that the participant could see the food. When the food was in full view, the rotation stopped, a light turned on in the loaded compartment, and the compartment door was unlocked. The participant was given several minutes to open the door and consume the food. If she or he did not do so, the experimenter opened the door manually from the programming area and waited for the participant to retrieve and consume the food.

If the participant closed the door after food retrieval, the light turned off, the door locked, and the now-empty compartments again rotated. If the participant did not close the door, the experimenter did so and implemented a nonverbal shaping program that continued until the participant was both opening and closing the door reliably. There were no programmed consequences for trying to open the empty, locked, dark compartment. Left-right position of food presentations varied unsystematically across trials, which began at 5–10 per session and increased gradually to 30 per session across several sessions. Compartment training continued until participants reliably opened and closed the door and made no attempts to open dark, empty compartments.

Delayed S+ training—Once compartment training was completed, simple discrimination training with the delayed S+ procedure began. The purpose was to teach participants to refrain from touching the compartment area when the light cue was not present, even if food items were visible within the dark compartments. A diagram of the delayed S+ procedure can be found in the leftmost portion of Figure 1. The S+ was defined as a lit compartment with a positive food or token, whereas the S– was defined as a dark compartment with either a positive or negative food or token. There was never a lit compartment with the negative food or token. At the beginning of a trial (Trial State 1 [TS1]), one food item (or token) was placed in each compartment. For example, for KVR, a blue M&M was placed in the left compartment and an orange M&M was placed in the right compartment. The foods were then rotated into full view, but the lights remained off. Depending upon the participant's behavior, the second phase of the trial (Trial State 2 [TS2]), in which one of the compartments was lit to define the stimulus designated S+, could commence

Several types of behavior were possible within this two-phase trial structure, and their immediate consequences were different. If the participant refrained from responding to the compartments for 3 s after trial initiation (i.e., during TS1), then the second trial state (TS2) could be initiated, and the participant could gain access to food by selecting the lit compartment. If the participant responded to the dark compartments at any point during TS1, however, he or she found the compartment door or doors locked, and the TS1 period was then extended for an additional 3 s. Further TS1 responses further extended the TS1 period.

If the participant did successfully refrain from responding during a TS1 period, the TS2 period could commence. A light was turned on in the compartment containing the S+ (designated arbitrarily by the experimenter according to a predetermined left-right position sequence), and the door was unlocked. The participant could then open the door and retrieve the food. After the participant closed the door, the light was turned off, the door was locked, and the compartment trays were rotated closed such that both compartments were empty to the participant's view. If the participant selected the S– compartment, the light in the S+ compartment was turned off, the door was locked, and both compartments were rotated.

When token stimuli were used, the delayed S+ procedure remained the same, except that the participant was required to insert a token into the slot to obtain food reinforcement, delivered into the food well directly below. Participants were not required to close the door or insert a token in any particular order. However, if the participant closed the door before insertion of the token, the next trial would not begin until the insertion was completed.

Intertrial intervals varied across participants, typically in the range of approximately 5–30 s. During that interval, an experimenter observed the participant to verify that she or he had completely consumed the food item from the previous trial. The next trial was not initiated until the participant did so and was facing the compartments. During intertrial intervals, there were no programmed consequences for touching dark compartments. Every delayed S+ training session consisted of 30 trials. Delayed S+ training continued until the participant

reached a “90%-90%” criterion (10% or less TS1 periods with responses and 10% or less TS2 periods in which the participant selected the dark compartment instead of the lit one) in a single session. Some minor exceptions to these criteria are noted in the Results section.

Delayed cue training—Upon completion of delayed S+ training, discrimination training continued with the use of a delayed cued procedure (see the rightmost portion of Figure 1). The S+ and S− stimuli remained the same as in delayed S+ training. As before, the S+ was a lit compartment with a positive food or token, but now the S− was a dark or lit compartment with a negative food or token. There was never a dark compartment with the positive food or token. At the beginning of a trial, two stimuli were rotated into the participant’s view, now with both lights turned on and the door to the S+ compartment: unlocked. After a brief delay, the light in the S− compartment was extinguished, thus signaling the correct compartment choice. At any time (either before or after the cue), the participant could open the door to the S+ to obtain the food or token. As before, every correct trial ended when the participant closed the door or deposited a token, or both. Touches to the S− compartment ended the trial without other programmed consequences.

On the initial trials of the delayed-cue procedure, the cue (i.e., extinguishing the light in the S− compartment) occurred after 500 ms. Subsequently, the cue was delayed progressively from trial onset in 250-ms increments until the delay reached 2 s. Every delayed-cue session consisted of 30 trials in which the position of the S+ varied unsystematically. Criterion was two consecutive sessions in which the participant responded to the S+ food (or token) on 90% of trials prior to the onset of the delayed cue.

Results

Compartment Training

All participants learned to reliably open and close the compartment doors to obtain foods during compartment training. Compartment training took an average of six sessions (range: 1–18).

Delayed S+ Training

Figure 2 and Figure 3 show that the delayed S+ procedure proved rapidly effective in reducing the tendency of 7 of the 8 participants to respond to dark compartments (mean: 8 sessions; range: 3–15 sessions); the 8th (JGR) underwent only four delayed S+ sessions for reasons that will be explained subsequently. In regard to the seven successful implementations of the delayed S+ procedure, reduction of TS1 responses was nearly complete in five instances and substantial in the remaining two.

Of the exceptions, KVR, NAS, and JGR all exhibited apparent stereotypic behavior that competed with the discrimination training. For KVR and NAS, this behavior was directed to the apparatus (e.g., repetitive manipulation of the compartment doors). Such behavior continued throughout the experiment despite a procedural requirement that a new trial could not be initiated until such activity had ceased for several seconds. By contrast, stereotypic behavior by JGR tended to take him away from the apparatus (e.g., pacing back and forth, motor stereotypies), perhaps resulting in the unusually long duration of compartment training (18 sessions vs. the next slowest, 13). For these 3 participants, we concluded that the stereotypic behavior was at best only minimally responsive to our programmed contingencies. Having no better alternative in service of our objectives, we elected to explore these participants’ response to the delayed cue conditions despite the stereotypy.

Participant TNT underwent two separate training episodes on the delayed S+ procedure, with four delayed cue sessions between them; atypically low, apparently stable inaccuracy during

the latter condition led us to return to the former in hopes of promoting more reliable control by the lit-versus-dark stimulus difference in delayed cue training. Figure 3 shows both delayed S+ training episodes. For both, S+ selection accuracy was very high throughout training. TNT's responses during TS1 tended to decline as training progressed. In the first (the panel marked TNT in the middle row in Figure 3), responses were made during TS1 on approximately 40% of trials throughout the first eight sessions and decreased to about 10% of trials by the final session. In the second, the percentage of responses during TS1 was less than 20% by the third session and remained low throughout the subsequent sessions.

One observation of note for most participants was the generally high level of stimulus control by the stimulus difference between the lit-versus-dark compartment from the virtual outset of training. If participants refrained from responding during TS1 and thus reached TS2, accuracy scores were never worse than 70% and frequently were much higher. Indeed, 6 participants achieved $\geq 90\%$ TS2 accuracy in their first session. These data are similar in character to those reported in earlier studies of the delayed S+ procedure, and we will consider them further in the Discussion section.

Delayed cue training

Participants' accuracy throughout delayed cue training is shown in Figure 4 and Figure 5. The bars show the percentage of trials on which the cue was delivered, and the filled circles show accuracy on trials during which choices were made before the cue. Accuracy on trials during which a cue was delivered was always high ($>90\%$) for all participants and is not shown. The cuing procedure was generally effective. On the first session of training, accuracy averaged 82.92% (range: 43.33%–100%) as indicated by the filled circles in the figures. Six of the 8 participants maintained reasonably high accuracy (generally $\geq 80\%$ correct selections) in subsequent sessions. Some participants did so from the outset of delayed cue training, frequently anticipating the cue correctly. Two participants (AXB, BAO) waited for cue onset on most of the initial trials, but both came to anticipate accurately within a few sessions.

Both KVR and TNT exhibited accuracy approaching chance levels. For TNT, accuracy dropped dramatically, from 100% at the end of delayed S+ training to 43.33%. Moreover, the majority of his responses were made before the cue (there were only 36.67% of trials on which he waited for it). After four delayed cue sessions, as noted earlier, he was given additional delayed S+ sessions and was then returned to the delayed cue procedure. On the first session of the return to delayed cue, accuracy for TNT was 80%, and he waited for the cue on 80% of trials. For KVR, accuracy dropped from 100% at the end of delayed S+ training to 66.67% on the first delayed cue session. Unlike TNT, KVR waited for the cue on 60% of the trials. By the seventh or eighth training session, his accuracy began to approach 80% and eventually 100%.

Performance on delayed cue training also can be examined in terms of the number of delayed S+ sessions participants received (see Table 2). Three participants received four or fewer delayed S+ sessions (few sessions), two participants received seven sessions (intermediate), and three received 10 or more sessions (many). Table 2 organizes performance on three aspects of delayed cue by these three categories. On average, participants who had few delayed S+ sessions also needed fewer sessions on delayed cue before maintaining high accuracy levels in the absence of a cue (5.67 sessions vs. 19.5 and 17.67 for those who had intermediate or many delayed S+ sessions, respectively). There was also a relation between the number of delayed S+ sessions and the percentage of trials on the first delayed cue session on which participants waited for a cue prior to making a response. In general, the more delayed S+ sessions, the more likely participants were to wait for a cue; participants who had many delayed S+ sessions waited, on average, for the cue on 77.56% of trials, while those who had intermediate or few sessions waited for the cue on 67.5% and 51.11% trials, respectively.

However, there did not appear to be a clear relationship between the number of delayed S+ training sessions and accuracy on the first delayed cue session. Participants who experienced the least or the most delayed S+ sessions were more accurate (90% and 93.33%, respectively) than those who experienced an intermediate number (75%).

All participants ultimately achieved high accuracy scores during the delayed cue training, which averaged 14 sessions (range: 3–29 sessions). By the end of training, discrimination accuracy was 99.04% (range = 95.04%–100%) and choices were made without the cue on virtually all trials.

Discussion

This study is perhaps the most systematic to date concerning methodology for initiating discrimination training for nonverbal children within a laboratory environment. In past work, various methods were used, many of which took advantage of behaviors established outside the laboratory (e.g., McIlvane & Stoddard, 1981; McIlvane, Withstandley, & Stoddard, 1984). Where no such behavior has been available, training has been a protracted process of trial-and-error experimentation.

Although targeted mainly at methodological development, our study also supports certain aspects of stimulus control topography coherence theory (McIlvane & Dube, 2003). The theory posits that discrimination baselines may involve a mixture of stimulus controls, each separable from the mixture via appropriate procedures. The delayed S+ procedure was designed to (a) discourage indiscriminant selections of specific food items or positions and thus to (b) render the experimenter-specified stimulus difference (lit vs. dark) likely to be captured by the programmed contingencies.

The controlling stimulus difference established in the delayed S+ training subsequently served as an effective prompt to establish new discriminations via the delayed prompting procedure for most participants. These generally good outcomes stand in contrast with the delayed-cue procedural failures that have been, reported with participants who functioned at very low behavioral levels (e.g., Oppenheimer, Saunders, & Spradlin, 1993). Perhaps our generally good findings were due in part to the combined use of the delayed S+ and delayed cue procedures in the context of a task that required discrimination of salient stimuli: food items or tokens that could be exchanged for food that differed along a primitive stimulus dimension, color (Gegenfurtner & Rieger, 2000).

Regarding points of particular interest within the data set, we note that all participants displayed a large number of responses during TS1, specifically during delayed S+ training. By the end of such training, however, the number of such responses was substantially reduced or eliminated for most participants. Moreover, TS2 accuracy was high from the outset of delayed S+ training for 7 of 8 participants. These results appear to answer in the negative a question posed by McIlvane and colleagues (2002), who asked whether a history of reinforced selections during trial-and-error training is necessary to secure rapid high accuracy when a delayed S+ procedure is implemented.

When switched from the delayed S+ to the delayed cue procedure, all but two participants (KVR and TNT) maintained accurate discrimination of the lit-versus-dark stimulus difference. Somewhat surprising, given the rationale for the procedures, however, is that waiting for the delayed cue was not consistently related to accurate selections. Both KVR and TNT, who exhibited the worst accuracy scores, waited for the cue on 40%–60% of trials. However, BYI exhibited an accuracy score above 80%, despite waiting for the cue on fewer than 25% of trials. It seems possible that waiting for the cue may have facilitated accuracy in some participants; AXB and BAO performed highly accurately and waited for the cue on over 90% of trials. Also,

during TNT's second episode of delayed cue training, he initially waited for the cue on 80% of trials and his accuracy was 80% (approximately twice the levels exhibited initially during his first exposure).

There did appear to be a relationship, however, between length of delayed S+ training and degree of waiting for the cue in the first delayed cue session: the more delayed the S+ experience, the more likely participants were to wait for the cue. For instance, AXB and BAO, who experienced the most delayed S+ sessions, exhibited the highest degree of waiting. The protracted delayed S+ training thus resulted in a greater number of trials on which the participants waited before responding. Perhaps that history promoted waiting when the procedure was shifted to delayed cue.

Gratified as we are about the good level of success that we achieved in initiating instruction with our exceedingly difficult participant population, we also recognize that these procedures require refinement. By the standards of mature instructional technology, the inter- and intraparticipant variability we observed was unacceptably high (cf. Sidman, 1960). For example, a substantial amount of variability was present in both conditions. (1) In delayed S+ training, some participants showed an immediate decline in TS1 responses (SBA, BYI), while others showed a more gradual decline (AXB, BAO) or no change (JGR). For most participants, high accuracy was exhibited in the first delayed S+ session, but for BAO, there was a gradual increase across sessions. (2) In the delayed-prompting procedure, only 3 participants showed near errorless learning. The number of trials on which participants waited for a cue tended to vary greatly both between and within participants over repeated sessions. Further, TNT showed quite different performances on the same procedure (delayed cue) at different times (the first vs. the second training episode).

These variable aspects of the data acknowledged, we saw little evidence of the protracted error patterns that are often associated with procedures that generate substantial error rates. Perhaps error patterns result mainly when the targeted stimulus control is not present in the behavioral baseline or has low initial frequencies relative to other irrelevant control (cf. Mackintosh, 1977, for a discussion of stimulus control "masking"). In the present study, the relevant stimulus control by the lit-versus-dark stimulus difference was apparently made probable by the combined delayed S+-delayed prompting procedure.

Perhaps one way to reduce inter- and intraparticipant variability is to combine the delayed S+ and delayed cue training procedures into a single procedure. For example, a trial could begin with the to-be-discriminated items presented in the compartments with the lights off. After a delay in which no responses are made to the compartments or the stimulus panel, one of two trial types could commence: (1) light-onset (i.e., TS2) trials like those in the current delayed S+ procedure or (2) delayed-cue trials like those in the procedure reported here. The goal of the former, of course, would be to maintain stimulus control by the lit-versus-dark stimulus difference. The latter would prompt selection of the S+. The relative proportions of each trial type could well be a variable in such a procedure, titrated perhaps on the basis of individual performance.

In the ideal situation, one would like to be able to eliminate or at least greatly reduce acquisition errors. Our apparatus has limitations, however, that may render the achievement of this objective difficult. One can envision fairly obvious ways to improve it, however. For example, one could reduce the initial error rate during the delayed S+ portion of the training if the transparency of compartment doors could be controlled. If semitransparency was achieved, for example, the appearance of food items in the compartments could be made less salient initially. It is possible, albeit expensive, to construct doors in which the transparency is continuously variable via the application of greater or lesser electrical currents. That acknowledged, it seems

reasonable to consider whether such expensive solutions are warranted or whether, under properly controlled conditions, low error rates are tolerable and may have no lasting effect on the ultimate achievement of low-functioning individuals in discrimination learning situations.

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Delayed S+ Procedure

Step 1: Both stimuli rotate into view. Both lights are off. Doors are locked.

Step 2: After no response for 3 s, a light turns on in the S+ compartment.

Step 3: After removing the stimulus and closing the door, the S- is rotated out of view.

Delayed Cue Procedure

Step 1: Both stimuli rotate into view. Both lights are on. S+ is unlocked.

Step 2: After a delay, the light in the S- compartment turns off.

Step 3: After removing the stimulus and closing the door, the S- is rotated out of view.

Figure 1.
The delayed S+ (left) and delayed cue (right) Procedures.

Figure 2.
Individual participant progress on delayed S+ training for AXB, BAO, BYI, and JGR.

Figure 3.
Individual participant progress on delayed S+ training for KVR, NAS, SBA, and TNT.

Figure 4.
Individual participant progress on delayed cue training for AXB, BAO, BYI, and JGR.

Figure 5.
Individual participant progress on delayed cue training for KVR, NAS, SBA, and TNT.

Table 1

Age, Gender, Diagnosis, and Language Age Equivalence for Each Participant

Participant	Age	Gender	Diagnosis	Language Age
AXB	18–07	Male	Autism	1–09
BAO	12–04	Female	Autism/PDD	<1–09
BYI	8–02	Male	FDD	1–09
JGR	11–02	Male	Autism	1–09
KVR	13–06	Male	Autism	2–08
NAS	10–09	Female	Autism	1–09
SBA	6–08	Male	Autism	1–09
TNT	11–06	Male	Autism/PDD	1–09

Note. Language age equivalence scores were obtained for all participants by using the Peabody Picture Vocabulary Test. In the age and language age columns, the first number indicates years and the second, months. PDD = pervasive developmental disorder.

Table 2
Number of sessions and Accuracy for the final Delayed S+ and initial Delayed Cue sessions

Participant	Delayed S+			Delayed Cue		
	No of Sessions	Final Accuracy	No. of Sessions	Initial Accuracy	Trial with Cue (%)	
BYI	3	100	11	83.33		23.33
JGR	3	100	3	90		70
SBA	4	100	3	96.67		60
Mean	3.33	100	5.67	90		51.11
KVR	7	100	10	66.67		60
NAS	7	100	29	83.33		75
Mean	7	100	19.5	75		67.5
AXB	14	100	17	100		96
BAO	15	100	24	100		100
TNT	10 (10)	100 (100)	4 (12)	43.33 (80)		36.67 (80)
Mean	13 (13)	100 (100)	15 (17.67)	81.11 (93.33)		77.56 (92)

Note. Data For TNT are shown for both the initial delayed S+ and cue set of sessions, and for the second set of sessions. The latter information is shown in parentheses.