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AN EXAMPLE OF DISCOVERY RESEARCH INVOLVING THE TRANSFER OF STIMULUS CONTROL

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The initial purpose of the present study was to replicate procedures for teaching preschool children to recruit attention at appropriate times by having an experimenter signal the availability and unavailability of attention (i.e., arrange a multiple schedule involving reinforcement and extinction; Tiger & Hanley, 2004). Following the development of discriminated social responding, the schedule-correlated stimuli were removed (i.e., a mixed schedule of reinforcement was arranged). However, discriminated responding continued during these conditions. Further evaluation suggested that stimulus control over children's social responding had transferred from the schedule-correlated stimuli to the delivery of reinforcement. The effect of a history of reinforcement under multiple-schedule conditions on performance under mixed schedules was then replicated with 2 participants in a reversal design. These findings suggest that following experience with schedule-correlated stimuli, these stimuli may be removed with only modest disruption to discriminated responding.

DESCRIPTORS: discovery research, mixed schedules, multiple schedules, preschoolers, rules, social behavior, stimulus control, teacher attention

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Advances in behavioral science emanate from two forms of research. In programmatic research, completion of one research project inevitably leads to the development of another project in a systematic line of inquiry. Progress is achieved in small increments as the believability of phenomena is established through both direct and systematic replications (Sidman, 1960). However on some occasions, an unexpected or unintended event results in a novel inquiry, otherwise known as discovery research. Several major advances in behavior analysis are a result of serendipitous events that stimulated discovery research. Skinner (1956/1972) provided anecdotes of two such discoveries: The effects of intermittent schedules of reinforcement came about following a need to conserve grain, and the extinction curve was discovered only when an automatic feeder jammed. Pavlov developed the classical conditioning paradigm when his dogs unexpectedly began salivating when an experimenter entered the room (see Babkin, 1949). Although most applied behavior-analytic research is driven by problems of immediate social importance, unexpected, yet practical, benefits may result from following Skinner's adage, "When you run onto something interesting, drop everything else and study it" (p. 104).

A recent publication by Roane, Fisher, and McDonough (2003) provides an example of this approach. The authors began a single-subject evaluation of the overjustification effect by identifying the baseline rate at which an individual with multiple disabilities completed a sorting task. A putative reinforcement contingency was then arranged by providing access to toys following engagement in the sorting task. However, sorting *decreased* under this contingency and subsequently increased when the reward contingency was removed (i.e., the opposite of what would be expected given both a reinforcement effect and subsequent over-

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justification effect). The authors then sought to determine why a reward contingency would result in decreased sorting. Several evaluations determined that sorting was a more preferred activity than toy play, and therefore arranging toy play to follow sorting approximated a punishment contingency.

Similar to Roane et al. (2004), the initial purpose of the current investigation was to follow a line of programmatic research. However, an unexpected finding led to the development of additional procedures to investigate these results. Initially we attempted to teach preschool children to recruit teacher attention at appropriate times by arranging the availability of attention into a multiple schedule of reinforcement. This procedure involved programming regular periods in which attention would and would not be available, providing children with continuous and distinct signals during both of these periods, and describing the different consequences for recruiting teacher attention (reinforcement or extinction) correlated with each stimulus (Tiger & Hanley, 2004). In an attempt to demonstrate functional control over the effects of the multiple-schedule arrangement on social approach responses, we eventually removed the schedule-correlated stimuli, in essence creating a mixed schedule of reinforcement (i.e., alternation of two different schedules in the absence of correlated stimuli). In contrast to the results of Tiger and Hanley, however, discriminated social responding persisted for both participants when the availability of teacher attention was seemingly unpredictable.

Based on this unanticipated finding, we chose to forgo the original question and attempt to understand the variables that influence mixed-schedule performance. Although it is difficult to determine when a researcher should "drop everything" and attempt to understand an unexpected relation, we thought this was an important area of inquiry because our results were inconsistent with previously published research (Hanley, Iwata, & Thompson, 2001; Tiger & Hanley, 2004). Also, identifying the relevant histories or present contingencies that result in discriminated responding in the absence of overt schedule-correlated stimuli may have practical implications. Finally, one of the later goals of our programmatic research, targeted to increase the social acceptability of procedures described by Tiger and Hanley (2004), was to eliminate the artificial signals by transferring stimulus control to events in the natural environment.

METHOD

Participants and Setting

Two preschool-aged children who were enrolled in a full-day, university-based inclusive preschool participated. Dena was a typically developing 4-year-old girl. Chad was a 5-year-old boy who had been diagnosed with nonspecified developmental delays. Dena and Chad were nominated for participation by their teachers for engaging in either poorly timed (Dena) or excessive (Chad) social approaches in the classroom. All sessions were conducted in a room (5 m by 5 m) arranged to emulate classroom periods in which a teacher provided instruction to 2 children simultaneously.

Response Measurement and Interobserver Agreement

The number of social approach responses, defined as any vocal (e.g., saying, "Look what I built") or nonvocal (e.g., handing a toy to the experimenter) behavior directed toward the experimenter; and the number of attention deliveries, defined as any vocal (e.g., saying, "Wow, that is a great tower") or nonvocal (e.g., giving the child a high-five) behavior directed toward the child, were recorded within 10-s intervals. An occurrence was scored following a 2-s pause between responses. Data were recorded using handheld computers and are reported as a response rate during reinforcement and extinction components.

Interobserver agreement was assessed by having a second observer simultaneously but independently score responses during at least 25% of sessions in all conditions for each participant. Agreement coefficients were determined by partitioning sessions into 72 10-s intervals and dividing the smaller number of responses by the larger number within each interval, and averaging these scores across intervals. Agreement for social approaches averaged 91% (range, 76% to 100%) for Dena and 89% (range, 78% to 100%) for Chad. Agreement for attention delivery averaged 96% (range, 86% to 100%) to Dena and 96% (range, 90% to 100%) for Chad.

Treatment Integrity

We assessed the integrity of implementation of the independent variable by determining the correspondence between the number of social approaches and the number of instances of attention delivery within reinforcement and extinction components of the mixed- and multiple-schedule arrangements. During reinforcement components, the smaller number of the two measures was divided by the larger number (components with zero social approaches and zero instances of attention were scored as agreements). During extinction components, this fraction was then subtracted from one. All measures were then multiplied by 100% to yield a treatment integrity score. For example, if three approaches were emitted during a reinforcement component and two instances of attention were scored, this would yield an integrity score of 67% for that component. However, if the same amount of each response was scored during an extinction component, this would yield a score of 33% for that component. These percentages were then averaged across sessions to yield a treatment integrity score of 98% for Dena and 96% for Chad.

Procedure

Sessions were similar to those described by Tiger and Hanley (2004). Children had access to academic materials (e.g., blocks, string beads) at individual tables across from and facing the experimenter. The experimenter looked down except when delivering contingent attention. There were three components in each session, one in which Chad's approach responses produced reinforcement (SR+) while Dena's were exposed to extinction (EXT_1), one in which Dena's approach responses produced reinforcement while Chad's were exposed to extinction, and one in which both children's approach responses were exposed to extinction (EXT_2). Each of the three components was presented twice for 1 min and once for 2 min (i.e., each component was scheduled for a total of 4 min) for a total session duration of 12 min. The order of components was randomly determined prior to sessions.

During SR+ components, approximately 5 s of attention was provided following each social approach response. While the SR+ component was arranged for 1 child, the other child's responding did not result in attention from the experimenter (EXT_1 component). This arrangement approximated classroom conditions in which a teacher would be able to attend to only 1 child. Attention was not available to either child during EXT_2. This component approximated classroom conditions in which the teacher would not be available to provide attention to any child (e.g., when talking with a parent). Thus, in the arranged conditions, attention could be available to Dena only, to Chad only, or to neither child, but attention was never available to both children simultaneously.

Mixed schedule (MIX). SR+, EXT_1, and EXT_2 components rotated on a time-based schedule, as described above, and component changes were unsignaled (i.e., no schedule-correlated stimuli were present). This condition served as a baseline from which the influence of schedule-correlated stimuli on children's social approaches would be assessed.

Multiple schedule (MULT). This condition was arranged similar to the MIX condition, except that a red, white, or blue floral lei was paired with each component. For example, when attention was available for 1 child, the experimenter wore the red lei; when attention was available for the other child, the experimenter wore the blue lei; and when attention was not available for either child, the experimenter wore the white lei. Floral leis were selected as schedule-correlated stimuli because they were portable, salient, and could be viewed by a child at any angle. The purpose of the MULT condition was to determine if correlating stimuli with the availability (SR+) and unavailability (EXT_1 and EXT_2) of attention was sufficient to bring children's social approaches under stimulus control.

Multiple schedule plus rules (MULT + rules). This condition was arranged similar to the MULT condition except that prior to each session the experimenter presented each lei and described the associated contingency. The contingencies were described as follows:

> When I am wearing the red lei, it is your time. I can answer your questions and look at your work. When I am wearing the blue lei, it is [other child's name] time. I can't answer your questions or look at your work. When I am wearing the white lei, it is my time. I can't answer either of your questions or look at either of your work.

Prior to each session, each participant was prompted to respond twice in the presence of each lei and to contact the contingencies associated with each. The purpose of this condition was to determine if providing rules prior to sessions would facilitate the stimulus control of social approach responses.

Variable interval (VI). Based on the obtained data, we hypothesized that the delivery of reinforcement for a social approach during the MIX condition would signal the availability of reinforcement for subsequent approach responses, until the participants encountered a nonreinforced approach response (i.e., the onset of extinction). To control for the putative discriminative aspect of reinforcement delivery, attention was arranged into separate VI schedules of reinforcement for each participant. Interval lengths were based on the mean interreinforcement duration from all sessions in the previous mixed schedule phase, which resulted in a VI 28-s schedule for Dena and a VI 26-s schedule for Chad. Reinforcement intervals were programmed into a desktop computer using a VI timer software program that signaled the experimenter when a reinforcer was arranged in each VI schedule. The computer monitor was placed to the side of the experimenter, facing away from both participants. In contrast to the MULT and MIX schedules, the programmed delivery of reinforcement during the VI schedule was not correlated with the availability of subsequent reinforcement.

RESULTS

The data for Dena and Chad are shown in Figure 1. During the initial MIX condition, both participants engaged in similar levels of responding across all three components (*M*s = 0.3 responses per minute during SR+, 0.9 during EXT_1, and 0.2 during EXT_2 for Dena and 3.1 during SR+, 3 during EXT_1, and 2.7 during EXT_2 for Chad). Following the introduction of schedule-correlated stimuli (i.e., MULT), Dena's responding increased similarly across all three components (*M*s = 2.5 responses per minute during SR+, 1.9 during EXT_1, and 1.4 during EXT_2). Chad's responding accelerated most during SR+ components (*M* = 8.2 responses per minute), although elevated levels of responding persisted during both EXT_1 (*M* = 3.8) and EXT_2 (*M* = 3.4) components. Because highly discriminated performance was not produced by the addition of schedule-correlated stimuli, presession rules were provided. Under these conditions, both participants responded at high rates during SR+ (*M*s = 9.3 responses per minute for Dena and 9 for Chad) and at lower rates during EXT_1 (*M*s = 0.3 responses per minute for Dena and

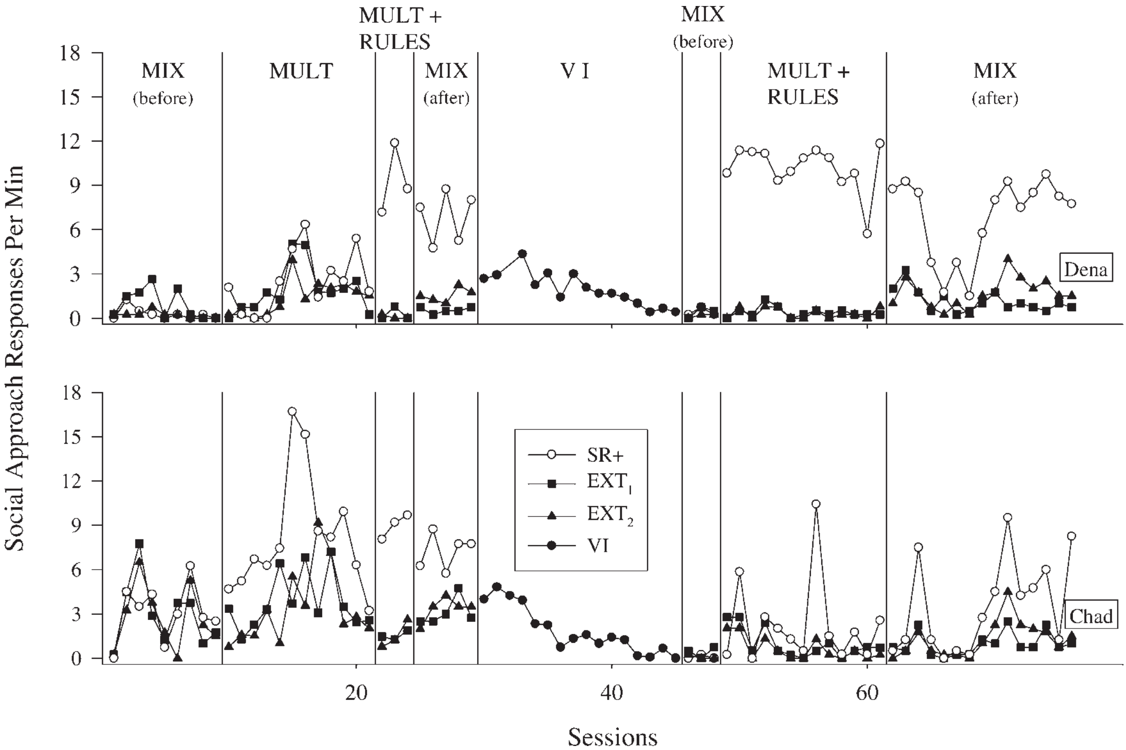

Figure 1. Social approach response rates across phases for Dena (top) and Chad (bottom). Data for Dena's Session 32 were lost due to an equipment failure.

1.5 for Chad) and EXT_2 (*M*s = 0.1 for Dena and 1.5 for Chad).

When we attempted to demonstrate functional control of the effects of contingency-specifying and schedule-correlated stimuli by returning to the MIX condition, both Dena and Chad continued to respond at high rates during SR+ (*M*s = 6.9 responses per minute for Dena and 7.3 for Chad) with lower rate responding during EXT_1 (*M*s = 0.6 for Dena and 3.1 for Chad) and EXT_2 (*M*s = 1.6 for Dena and 3.4 for Chad). This was surprising, because in previous research (Hanley, Thompson, & Iwata, 2001; Tiger & Hanley, 2004) discriminated social approaches failed to be maintained in the absence of programmed schedule-correlated stimuli.

Data obtained for both participants provided evidence that the delivery of reinforcement set the occasion for more responding during the unsignaled SR+ components. Figure 2 shows the mean interresponse times (IRTs) during MIX and VI conditions. During the MIX condition that followed the MULT + rules condition, if a response was followed by attention, Dena typically responded again after a relatively short pause (IRT = 6 s). If a response was not followed by attention, however, she typically responded again after a relatively long pause (IRT = 56.8 s). Similarly, if a response from Chad was followed by attention, he typically responded again after a short pause (IRT = 7.4 s) and, if a response was not followed by attention, he typically paused for a longer time before his next response (IRT = 19.4 s). In addition, the standard deviation was considerably smaller given a reinforced response relative to a nonreinforced response for both participants (*SD* = 4.8 and 22.9, respectively, for Dena and 2.7

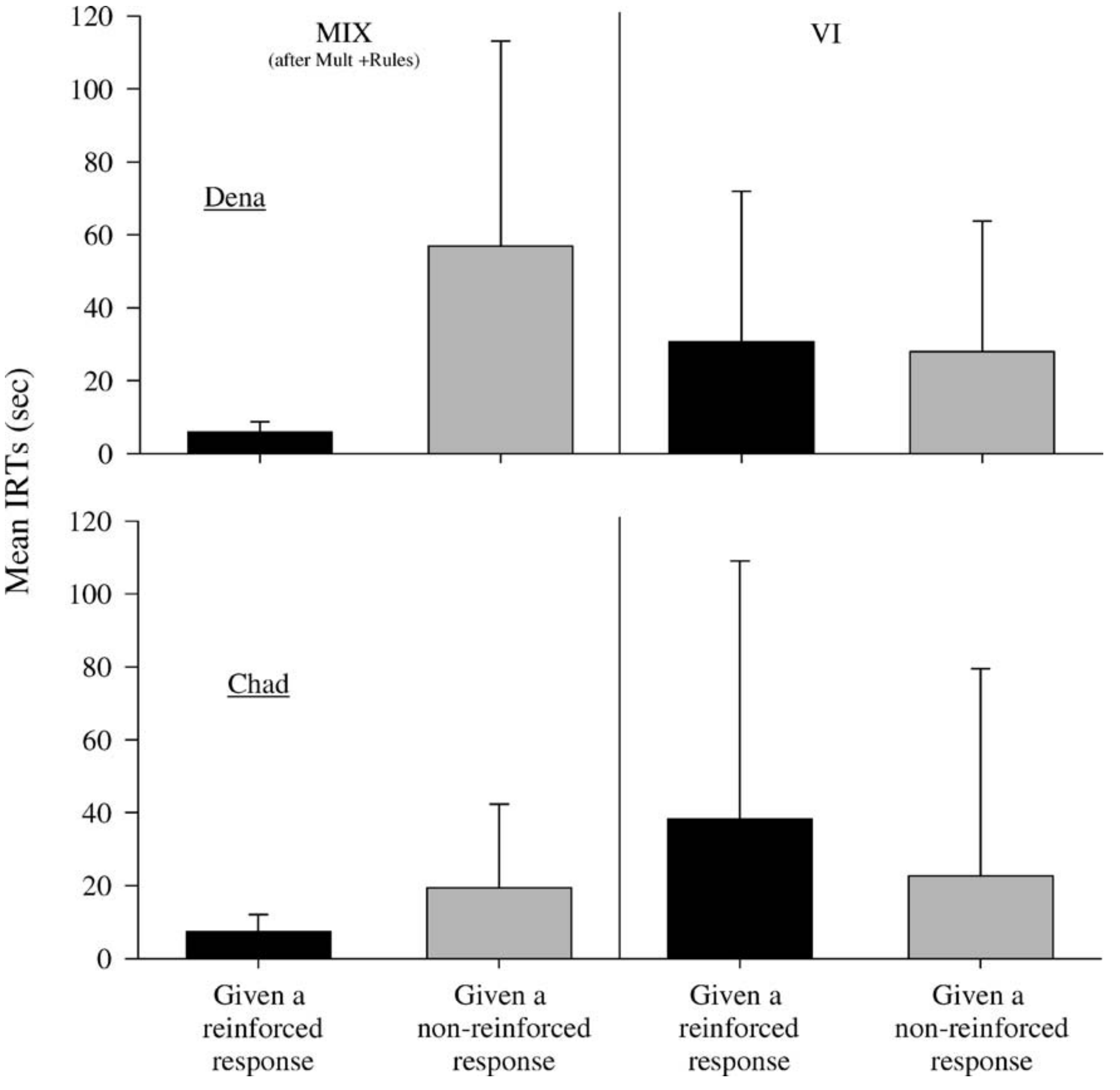

Figure 2. Means and standard deviations of interresponse times (IRTs) when responses were followed by reinforcement (black bars) or no reinforcement (gray bars) during mixed and variable-interval schedules of reinforcement.

and 56.3, respectively, for Chad). These data suggest that the delivery of reinforcement affected responding under MIX conditions, in that responding differed following the delivery or nondelivery of attention. That is, it appeared that reinforcer delivery was discriminative for further responding.

To disrupt the potential discriminative control of reinforcement delivery, we programmed independent VI schedules for each child. Both participants' response rates gradually slowed (*M*s = 1.9 responses per minute for Dena and Chad, Figure 1). Analysis of the IRTs during the VI condition showed similar pause durations for Dena when a response did (IRT = 30.8 s) or did not (IRT = 27.9 s) result in the delivery of attention (Figure 2). Chad actually paused longer following a response that resulted in attention (IRT = 38.2 s) than following a response that did not result in attention (IRT = 22.6 s; Figure 2). These data also suggest that the discriminative properties of the delivery of reinforcement were disrupted by the VI schedules.

Following the VI condition, attention was again arranged into MIX conditions (sixth phase of Figure 1); however, this time both participants responded at low and indiscriminate rates across all three components (*M*s = 0.4 responses per minute during SR+, 0.4 during EXT_1, and 0.2 during EXT_2 for Dena and 0.1 during SR+, 0.4 during EXT_1, and 0.1 during EXT_2 for Chad). To replicate the previously observed discriminated performance under MIX conditions, the MULT + rules condition was reimplemented. Dena again responded at high rates during SR+ (*M* = 10.2) and at low rates during EXT_1 (*M* = 0.4) and EXT_2 (*M* = 0.3). Chad responded at lower rates than observed previously during SR+ (*M* = 2.3), but higher than in EXT_1 (*M* = 1) and EXT_2 (*M* = 0.6). When the MIX condition was reinstated, Dena responded at high rates during SR+ (*M* = 6.2) and low rates during EXT_1 (*M* = 1.2) and EXT_2 (*M* = 1.7). Chad similarly responded at higher rates during SR+ (*M* = 3.5) than during EXT_1 (*M* = 1) and EXT_2 (*M* = 1.3), although this effect was less clear than with Dena. Nevertheless, these patterns were similar to those observed earlier in the analysis and suggested that discriminated responding under a mixed schedule of reinforcement developed only following an immediate history of discriminated performance under MULT + rules conditions.

The necessity of the MULT + rules history on the development of discriminated performance under MIX conditions is highlighted by the discrimination indexes presented in Figure 3, which were calculated by summing the number of responses emitted during SR+ components and dividing these by the total number of responses emitted across all components. Given that reinforcement was available for one third of each session, indiscriminate responding (i.e., that occurring at chance levels; dotted lines on Figure 3) would result in an index close to .33. By contrast, perfect discriminated responding would result in an index of 1. During the initial MIX condition (i.e., that which preceded MULT + rules) both participants responded at near-chance levels (indexes of .18 for Dena and .32 for Chad). However, in the MIX condition that followed the MULT + rules condition, both participants responded at above-chance levels (.77 for Dena and .52 for Chad). Once the discrimination had been disrupted by the VI history, both participants responded at near-chance levels during the subsequent MIX conditions (.42 for Dena and .17 for Chad). Under MIX conditions that followed MULT + rules, both participants responded at above-chance levels (.68 for Dena and .59 for Chad). It should be noted that these indexes were somewhat lower than those achieved under the MULT + rules arrangement (.94 for Dena and .75 for Chad; dashed lines on Figure 3).

DISCUSSION

The current study replicated the multiple-schedule procedures used by Tiger and Hanley (2004), and the results demonstrated that discriminated performance failed to develop under a multiple-schedule arrangement until contingency-specifying statements were provided. However, these results differed from those of Hanley et al. (2001) and Tiger and Hanley in that discriminated performance persisted in the absence of schedule-correlated stimuli when the multiple-schedule intervention was removed. The results of subsequent analyses suggested that this responding was occasioned by the delivery of attention.

Previous research has demonstrated that the delivery of reinforcement may serve as a discriminative stimulus for behavior that is historically maintained by its delivery. For example, Spradlin, Girardeau, and Hom (1966) trained individuals with mental retarda-

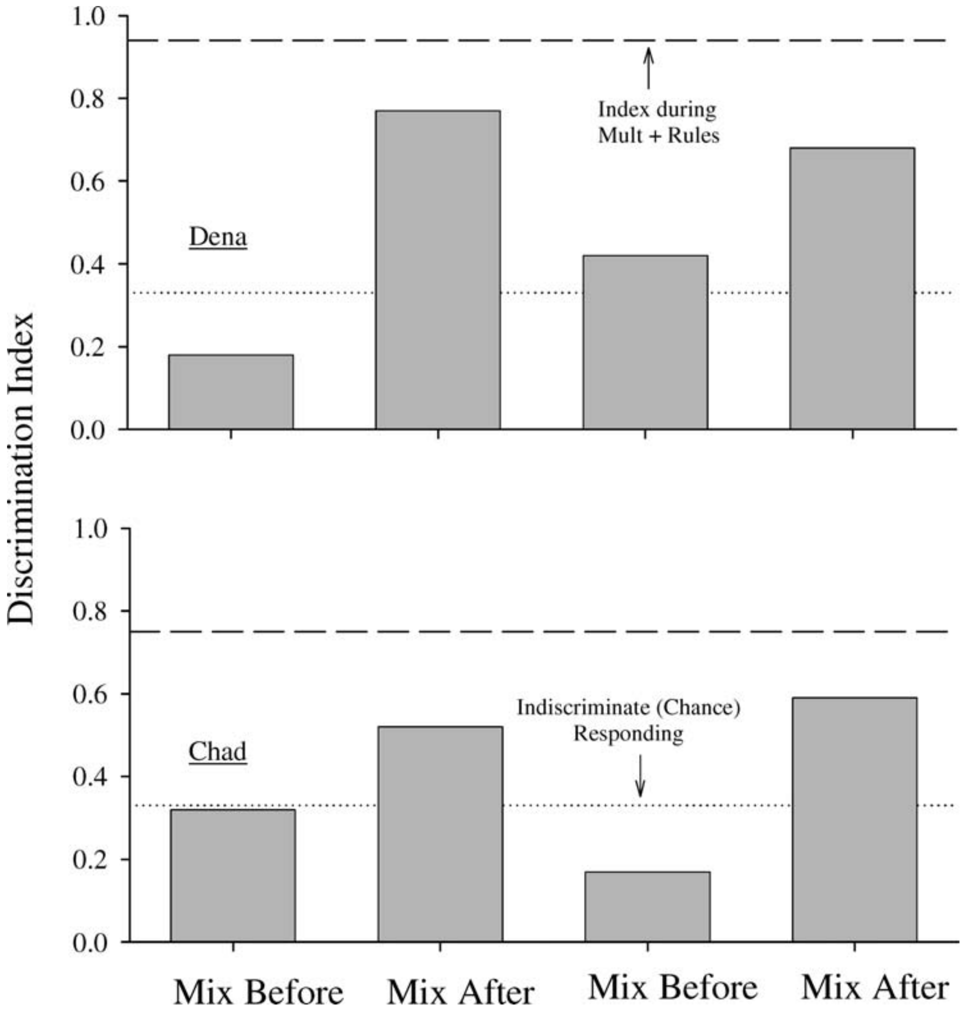

Figure 3. Discrimination under MIX conditions both before and after MULT + rules history, relative to chance levels of responding (dotted line) and to responding under the MULT + rules arrangement (dashed line).

tion to pull a lever to earn tokens. Lever pulling was placed on extinction after an initial reinforcement effect was observed. Following a period of nonresponding during extinction, tokens were occasionally delivered. For some participants, lever pulling increased following the delivery of the tokens relative to periods in which tokens were not delivered. Thompson, Iwata, Hanley, Dozier and Samaha (2003) reported similar results when they compared extinction, differential reinforcement of other behavior (i.e., reinforcement is delivered contingent on not engaging in the target response), and noncontingent reinforcement (i.e., reinforcement is delivered independent of responding) as control procedures for simple appetitive responses in adults with developmental disabilities. Extinction resulted in the most rapid reduction in responding, in that the delivery of reinforcement under the two other conditions continued to occasion responding.

During the MIX conditions of the present study, the delivery of attention following a social approach was highly predictive of continued availability of attention, and a nonreinforced response was highly predictive of continued unavailability of attention. For instance, SR+ components lasted for either 1 or 2 min each, such that if attention was delivered early in the component, it was available for at least another minute. This predictability was eliminated by programming attention on a VI schedule of reinforcement, in which the delivery (or nondelivery) of attention was no longer predictive of its subsequent availability. The lack of predictability was evident in the data, in that both participants responded similarly following a reinforced or nonreinforced social approach under VI conditions. Following additional MULT + rules training, the predictability of reinforcer delivery again controlled children's social approaches, in that discriminated responding persisted under MIX conditions.

In addition to the discriminative properties of attention delivery, it is possible that the rules provided during the MULT + rules arrangement may have continued to influence children's social approaches under the mixed schedule. However, the rules described the consequences for responding in the presence of each of the three floral leis, and in the absence of the leis in the MIX condition, the rules were no longer relevant (i.e., the rule, "I can answer you when the red lei is present," would not control behavior in sessions in which no leis were present). Thus, the hypothesis that the saliency of reinforcer delivery (or nondelivery) during the MULT + rules condition served as the discriminative stimulus for continued responding (or pausing) during subsequent MIX conditions seems to be a more parsimonious explanation for the obtained results. It is also possible that the consequences for the other child's responding may have signaled the differential availability of reinforcement. That is, the experimenter responding to Chad's social approaches could have signaled the unavailability of attention to Dena (i.e., when the SR+ component was scheduled for Chad, the EXT_1 component was scheduled for Dena). Similarly, the nondelivery of attention following a social approach from Chad could have signaled the potential availability of attention for Dena (i.e., when extinction was arranged for Chad, either the SR+ or EXT_2 component was arranged for Dena). There is some evidence that the consequences for Chad's responding served as discriminative stimuli for Dena. For example, when Chad engaged in high-rate responding during the second and fourth MIX conditions, Dena approached the experimenter more frequently during EXT_2 components (i.e., when Chad's responding was not reinforced) than during her EXT_1 components (i.e., when Chad's responding was reinforced). However, these differences were not large or stable, and Chad's data did not reveal the same pattern.

Because we followed an unexpected result in this study, we discovered a means of achieving discriminated social responding during periods in which the availability of social reinforcement was seemingly unpredictable. However, this finding may be an artifact of the particular procedures we employed and the effect may be short-lived, in that the effects with Chad were not robust and decreased over time. Likewise, the availability of teacher attention may fluctuate more rapidly in the natural environment than was programmed in our arrangement. These more complex unsignaled reinforcement schedules in classrooms would require children to respond more frequently to come under the control of the operating contingency. Finally, these results may have limited generality in that discriminated performances observed in the current study were not observed in other investigations that employed similar conditions (Hanley et al. 2001; Tiger & Hanley, 2004). Therefore, future research should continue to identify relevant histories that will result in desirable patterns of social approach responding in the classroom in the absence of highly predictive cues.

There are many stimuli in the natural environment that may signal the unavailability of teachers' attention (e.g., when a teacher is engaged with other students, on the phone with a parent, collecting data) that may require an extensive history of unsuccessful or punished responding for behavior to come under the control of all these signals. Transferring the control of behavior from artificial signals (e.g., a floral lei) to those that occur more naturally in the environment may then be a desirable long-term goal (see Cuvo, Davis, O'Reilly, Mooney, & Crowley, 1992, for an example). One strategy for transferring stimulus control might involve initially presenting the artificial signals continuously, as was done during the MULT + rules phases of the current study, while pairing them with more natural cues, such as body posture or a vocal invitation (e.g., saying, "What can I do for you?" while wearing a lei). The presentation of the artificial signals could be gradually reduced in duration such that the more natural vocal signal could eventually be provided at the onset of the period in which reinforcement is available, and a different vocal signal could be provided at the onset of an extinction period (e.g., "Everyone, I am going to work with Billy now"). Transferring stimulus control to more natural and brief cues may make such procedures more manageable for teachers and perhaps promote their adoption.

In addition to practical implications for promoting discriminated social responding of preschoolers, the present study also contributes to the small body of applied research that has demonstrated the effects of idiosyncratic histories of reinforcement on the effectiveness of behavioral interventions. That is, historical contingencies of reinforcement may come to control behavior to the exclusion of a prevailing set of contingencies that operate in the individual's environment. For example, Progar et al. (2001) conducted a functional analysis of aggression with an institutionalized adult who was transferred from another facility. This individual engaged in escape-maintained aggression during sessions conducted by familiar therapists (i.e., those who had historically provided escape following aggression) but not during sessions conducted by novel therapists. In the present study, Dena and Chad initially did not engage in discriminated social approaches under MIX conditions. However, once they had experienced a history of reinforcement under the MULT + rules conditions, the schedule of reinforcement continued to control responding in the absence of the schedule-correlated stimuli (i.e., when the MIX condition was reinstated). Future research should continue to determine the conditions under which different histories enhance or compromise the influence of prevailing contingencies (see also Ringdahl, Vollmer, Borrero, & Connell, 2001).

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