REINFORCING VARIABILITY IN ADOLESCENTS WITH AUTISM

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Five adolescents with autism, 5 adult control participants, and 4 child controls received rewards for varying their sequences of responses while playing a computer game. In preceding and following phases, rewards were provided at approximately the same rate but were independent of variability. The most important finding was that, when reinforced, variability increased significantly in all groups. Reinforced variability could provide the necessary behavioral substrate for individuals with autism to learn new responses.

DESCRIPTORS: autism, operant variability, response stereotypy, percentile reinforcement, noncontingent reinforcement

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Autism is characterized by repetitive or stereotyped behavior (Hertzig & Shapiro, 1990), including body movements, echolalia (repetitive vocalizations), fixed routines, conversation, and preoccupation with particular objects (Baron-Cohen, 1989). Repetitive behaviors are observed in experimental as well as natural settings. For example, Frith (1972) found that, when asked to place colored stamps on paper, children with autism generated patterned sequences; nondisabled and mentally retarded children showed greater sequence complexity. The children with autism tended to use only a subset of the available colors, whereas the comparison children sampled more alternatives. Boucher (1977) asked children with autism and those without to choose one of two arms of a T-shaped maze. The children with autism repeatedly chose one arm, whereas the controls varied between the two. When a third arm

was added, participants with autism were more likely than controls to ignore the new option. Baron-Cohen (1992) asked children with autism and controls to hide a penny in one hand so that the experimenter could not guess the location. Those with autism were more likely than those without to generate a simple, predictable pattern, such as switching back and forth from left to right hands.

Such repetitive responding can result in loss of reinforcement. For example, Mullins and Rincover (1985) asked children with and without autism to pick one of five cards. Sometimes food reinforcers were found in a cup behind the card, and sometimes not. Each of the five cards was a discriminative cue for a different schedule of reinforcement, including continuous reinforcement (CRF), fixed-ratio (FR) 2 (every second choice was reinforced), FR 4 (every fourth choice was reinforced), FR 7, and FR 11. Control participants sampled all five alternatives and quickly learned to choose the most frequently reinforced card or the CRF alternative. Children with autism sampled only a limited number of cards and often preferred a nonoptimal alternative. These studies indicate that operant responding of children with autism tends to be less variable than normal,

and this can interfere with adaptive responding.

Reinforcement can modify stereotyped responding (e.g., Handen, Apolito, & Seltzer, 1984; Iwata, Pace, Cowdery, & Miltenberger, 1994; Kennedy & Haring, 1993). For example, differential reinforcement of other behaviors (DRO) and of low rates of responding (DRL) can decrease self-injurious and stereotyped behaviors (e.g., Gunter et al., 1984; Smith, 1987; Wong, Floyd, Innocent, & Woolsey, 1991). Handen et al. differentially reinforced low rates (DRL) of repetitive speech in adolescents with autism. Smith provided reinforcement to an adult with autism for not engaging in pica (DRO). Kennedy and Haring (1993) provided reinforcement to teenagers with autism for not engaging in disruptive repetitive behaviors in the classroom (DRO). In each of these cases, the goal was to decrease nonfunctional and maladaptive responding.

An alternative treatment approach might be to increase response variability directly. Variability is incompatible with stereotypy, and a baseline of variable responding could enable selection of new and adaptive behaviors. Previous research with animals and people has shown that variability is increased by reinforcers contingent on it (Holman, Goetz, & Baer, 1977; Machado, 1989; Neuringer, 1986; Page & Neuringer, 1985; Pryor, Haag, & O'Reilly, 1969). In a study related to the present one, Saldana and Neuringer (1998) reinforced playing a computer game in which two response keys were pressed by children with attention deficit hyperactivity disorder (ADHD) and control participants. When reinforcement was contingent on variability of response sequences, variability increased significantly in both groups. Thus, response variability in individuals with ADHD was directly controlled by reinforcers contingent on behavioral vari-

ability. Might the same apply to individuals with autism?

We anticipated a potential problem in seeking an answer: The baseline variability of individuals with autism might be so low as to make its reinforcement difficult or impossible. Our solution was to employ a percentile reinforcement schedule under which the criterion for reinforcement is continually recalculated based on an individual's recent performance (Galbicka, 1994). As an example, assume that one is attempting to increase response force. The last 10 responses would be ordered, from highest force to lowest, and the criterion set at a particular level in the hierarchy (e.g., at 50%). The next response would be reinforced only if its force were greater than the forces of 50% of the preceding 10 responses. Thus, even if only very weak responses were present at first, the most forceful 50% of these would be reinforced. Percentile reinforcement procedures have previously been applied successfully to dimensions such as response rate, and Machado (1989) used such procedures to generate variability in pigeons' responding. However, we know of no study in which people, with or without autism, received reinforcement under a percentile schedule (Galbicka, 1988).

In the present experiment, individuals with autism and two control groups, one college-aged adults and the other children, played a computer game in which presses on two buttons, left (L) and right (R), were occasionally reinforced. Responses were segregated into trials, each consisting of four responses. Sixteen different sequences, or patterns of L and R, were possible (e.g., LLRL, RRLL, LLLL, etc.). After preliminary training, participants were rewarded following a randomly selected 50% of trials (PROB1). Under this condition, rewards were independent of the particular patterns, and therefore were independent of variability. In the second phase (VAR), participants received re-

inforcement under a percentile reinforcement schedule only if the response patterns varied. Lastly, participants were returned to probabilistic conditions (PROB2) identical to PROB1. The experimental design was therefore ABA, with reinforcers provided independent of variability in the A phases and contingent upon variability in B.

Based on previous findings, we predicted that sequence variability would be higher in the control participants under VAR than under PROB1 and that this increased variability might persist into the postexperimental PROB2 phase (Neuringer, 1986; Saldana & Neuringer, 1998). The main question was whether VAR contingencies would increase variability in children with autism. If so, response repertoires in these individuals could be broadened by explicitly reinforcing variability. Repetitive responding could thereby be discouraged, and the variable substrate could permit selection of new responses.

METHOD

Participants

The experimental group consisted of 3 males and 2 females, 12 to 17 years of age, who had been diagnosed with autism and were in a residential treatment program. Mary was 15 years old and had been diagnosed with autism and cerebral palsy; Sarah was 17 years old and had been diagnosed with autism, mental retardation, and bipolar disorder; Greg was 17 years old and had been diagnosed with autism, mental retardation, and cerebral palsy; Joe was 14 years old and had been diagnosed with autism, epilepsy, and developmental delay; and Adam was 12 years old and had been diagnosed with autism and mental retardation. Scores on the Vineland Adaptive Behavioral Scale assessed mental ages as ranging from 23 to 51 months. Four of the 5 participants were taking prescribed medications, including buspirone, lithium carbonate, carbamazepine, sodium valporate, Vitamin B6, and magnesium. Administration of these drugs was consistent throughout the experiment.

Adult control participants consisted of 3 male and 2 female college students who had no diagnoses of physical or psychological impairments. Child control participants consisted of 3 males and 1 female, 4 to 9 years old, who had no diagnoses of physical or psychological impairments.

Apparatus

A Macintosh Color Classic computer (with a screen 17.15 cm by 12.7 cm) was connected to two large mouse buttons (with tracking mechanism removed) mounted in a gray wooden box (45.72 cm long by 17.15 cm wide by 5.72 cm high). These buttons were 17.15 cm apart and served as left and right operanda. The button console was located 10.16 cm directly in front of the computer, and each participant sat in a chair facing the computer, with the experimenter sitting nearby.

Procedure

Computer game context. A 0.1-s 1800-Hz tone resulted from right-button presses, and an equal duration 2800-Hz tone resulted from left-button presses. Trials consisted of four presses, with reinforcement at the end of a trial consisting of a series of rising 0.1-s tones (800, 1600, 2400, and 3200 Hz) accompanied by a green "smiley face" (1.9 cm in diameter) that appeared in a gray equilateral triangle centered on the computer screen. The smiley faces filled the triangle from left to right, bottom to top, until the entire triangle was filled. Nonreinforced trials terminated with a single 500-Hz 0.3-s tone, and no smiley face was added to the screen. Between trials, a 0.5-s pause was required. If a button was pressed sooner than 0.5 s after completion of the previous trial, a red "stop" box appeared at the bottom of

the screen, remaining until 0.5 s passed without a response. If both buttons were pressed simultaneously, no tone was sounded, and the red stop box appeared, again remaining for 0.5 s. Button presses that occurred when the red box was on the screen produced no tones, were not registered, and resulted in the 0.5-s pause being extended until a full 0.5 s passed without a response. In summary, for 0.5 s following each trial and when the red stop box was present, presses were not counted toward meeting the trial contingency.

When a triangle was filled with smiley faces, thereby completing one game, the computer displayed a series of larger (8.89 cm in diameter) smiley faces of various colors (blue, pink, yellow, and green) accompanied by a computer-generated song. The songs cycled through "Yankee Doodle," "Be Kind to Your Web Footed Friends," "Old MacDonald," and "Row, Row, Row Your Boat." In addition to the song and graphics display, participants received a tangible reinforcer (e.g., a piece of candy or 25 cents) whenever a triangle was completed. Thus, the small smiley faces served as second-order conditioned reinforcers, the large smiley faces with song served as first-order conditioned reinforcers, and the candy or money served as tangible reinforcers. Each completed triangle constituted one game. As described below, in different phases and depending on the participant, different numbers of smiley faces (6 to 15) were required to fill the triangle and complete a game.

VAR Reinforcement Contingencies

Under the VAR contingencies, only relatively infrequent sequences were reinforced. Relative frequency (RF) values were calculated as follows.

RF value. Sixteen counters kept track of the number of occurrences of each of the 16 possible patterns of four responses (e.g.,

LLLL, LLLR, LRLR). Each of these 16 patterns was then assigned a weighted RF value based on the relative frequency with which it had occurred in the recent past. The RF value for each pattern was equal to the counter for the particular pattern divided by the sum of the counters for all 16 patterns, weighted as described below. RF values varied between 0 (lowest possible relative frequency of a pattern) and 1.0 (highest possible relative frequency).

Weighting coefficient. After each reinforcement, all 16 counters were multiplied by a weighting coefficient equal to .97. A pattern's RF value was thus equal to its number of occurrences, adjusted according to this weighting coefficient, divided by the sum of all 16 adjusted counters. The weighting coefficient made the RF values differentially sensitive to recent occurrences of a pattern, with patterns emitted long ago contributing less to the RF values than recently emitted patterns. For example, if a given pattern had last occurred 10 reinforcements ago, its counter would have been multiplied by .97 10 times, thereby lowering its RF value. More precisely, the contribution to the RF value of any particular trial decreased exponentially with reinforcements.

Percentile reinforcement contingencies. Whenever a sequence was emitted, its current RF value was entered into a list that kept track of the most recent 20 RF values (i.e., those associated with the 20 most recent trials). This list was updated after every trial, so that the list provided a moving window of the RF values for the participant's 20 most recent sequences. The RF values in the list were ranked, with the 11th lowest value providing the criterion for reinforcement. Sequences with an RF value less than this criterion met the variability contingencies and were reinforced. Values equal to or higher than the criterion were not reinforced. As a participant's recent RF values changed, so did the criterion. Thus, as is generally true

for percentile reinforcement schedules, these contingencies systematically "pushed" the participant; in this case toward increasing variability. There was one additional aspect to the contingency: To be reinforced, the RF value of the emitted sequence had to be less than or equal to .35. This maximum assured that a participant would not receive reinforcement for alternating among only two or three patterns. In summary, if the RF value of the current sequence was lower than the 11th lowest during the last 20 trials and was less than or equal to .35, the sequence was reinforced; otherwise, no reinforcement occurred.

PROB Reinforcement Contingencies

The task was identical to that under VAR (i.e., four responses per trial, each trial ending with reinforcement or not, same reinforcements) except that reinforcement was given with a probability of .5 and was independent of sequence variability. Under PROB contingencies, sequence variability was permitted but was not required.

Design

Preliminary training. During preliminary training, reinforcers were provided according to a 1.0 PROB schedule (every trial ended with reinforcement) followed by a .75 PROB schedule (75% of trials, randomly selected, resulted in reinforcement). For participants in all groups, three or four preliminary games were provided, the one exception being Mary, who received eight training games.

Experimental group. Participants with autism received approximately 10 sessions of training over a 1-month period. Sessions were conducted in a secluded area of the group homes where the participants lived. Prior to the beginning of a session, each participant chose a favorite treat from a selection of food reinforcers (e.g., M&Ms®, potato chips, raisins, gummy bears). These

were used as reinforcers for that session, and were presented at the conclusion of each game when a triangle had been filled with small faces. Participants were read simple instructions at the beginning of their first session:

> This is a computer game. You can make smiley faces appear on the screen by pressing these two buttons. If you fill the triangle with smiley faces, you get [name of a food reinforcer]. If you see a red box, that means wait a second.

No further instructions were provided, except in the rare case in which a participant responded on only one button repetitively for an extended period of time during training and was reminded, "Remember, there are two buttons."

Each session consisted of 5 to 13 games and lasted between 15 and 30 min, depending upon the participant's willingness to continue. After an initial period with six smiley faces per game, the triangles were increased to 10 faces per game. Therefore each session consisted of between 100 and 260 four-response trials. Responding in the first 300 trials was reinforced under the probabilistic contingencies (PROB1). The number of trials in the PROB1 phase was constant across participants, but the number of games differed (ranging from 14 to 27) due to differences in how many games each participant played using the smaller (six-face) triangle size. Responding in the next 35 games (approximately 700 trials) was reinforced under the percentile VAR schedule. Responding in the final 15 games (approximately 300 trials) was once again reinforced probabilistically (PROB2). Changes in contingencies occurred between games and were not announced.

The reinforcers for some participants in the experimental group changed over the course of the experiment to maintain responding. For Mary and Adam, an FR

schedule was established that employed picture cards as discriminative cues. The first six to eight cards on the schedule were pictures of a triangle, and each time a game was completed, one card was removed. The last card in the ratio contained a symbol for a reinforcer such as "toys," "van ride," "puzzle," or something "pretty." To receive the reinforcer at the end of the FR, the individual had to complete the number of triangles specified. Both participants were familiar with this procedure and with the symbols, and they successfully completed the required number of triangles. For Greg, an additional reinforcer was added so that every completed triangle resulted in a prize card from "The Price Is Right Board Game" and a series of game-show quotes read by the experimenter. The picture cards helped to maintain task-directed behaviors. For all participants, the smiley face reinforcers were intermittently accompanied by verbal praise and encouragement.

Adult control group. Participants in this group played the same series of computer games as the experimental participants, but the games were combined into a single 1-hr session consisting of 34 games (triangles). Participants were read the same instructions as the experimental group and received a brief written explanation of the rules of the game: "In the game, you will be pressing two large buttons, trying to make smiley faces appear on the screen. When you fill a triangle with smiley faces, you will receive a quarter." Reinforcement consisted of 25 cents for every completed triangle, with a total of $8.50 for the session. Following preliminary training, each triangle consisted of 15 smiley faces, so that each game contained about 30 trials. There were four games of preliminary training, followed by 10 games (approximately 300 trials) under PROB1, 10 games (approximately 300 trials) under VAR, and then 10 more games (approximately 300 trials) under PROB2. Due to a

procedural error, Cindy received 15 games under each condition.

Child control group. The children in this group participated in two sessions, each consisting of 23 or 24 games and each lasting approximately 45 min. The triangles consisted of 10 smiley faces, so that each game included approximately 20 trials. After two games of preliminary training, there were 15 games (approximately 300 trials) under PROB1, then 15 games (approximately 300 trials) under VAR, followed by 15 more games (approximately 300 trials) under PROB2. Prior to the session, participants were read the same instructions as the other two groups. The reinforcement protocol was similar to the schedules used for experimental-group participants Mary and Adam. After a triangle had been completed, each participant received a sticker (e.g., train cars, butterflies), which he or she placed on a chart to make a picture. After two pictures had been completed, the participant chose a prize from a selection of toys and the session terminated. The toys were worth between $3.00 and $6.00 each, and ranged from toy magnets and cars to children's art supplies and stuffed animals. The same procedure was used in the second session. One participant in this group, Alice, experienced triangles containing 15 smiley faces and chose to stop playing after completing only half of the PROB2 phase.

Measures. Two measures were used to evaluate sequence variability: average RF value per game and U value. Each sequence was associated with an RF value, as described above. The RF values for all trials within a single game (complete triangle) were summed and then divided by total number of trials in that game to obtain the average RF value for that game. The lower this average, the more variable the sequences.

U values provided an index of sequence uncertainty during the last 150 trials of each of the three phases. U values were calculated

using the formula: $U = -\Sigma[(N_{1\text{-}16})^*(\log_2[N_{1\text{-}16}])]/\log_2(16)$, where N equals the frequency of occurrence of a given pattern divided by the sum of all frequencies, or total trials. U values range from 0 to 1, with higher values indicating more equal distributions among the 16 patterns, or higher variability. U and RF values represent different dimensions of variability: The RF value is a function of relatively recent responses, and the U value indicates more molar distributions of sequence frequencies at the end of a phase.

RESULTS

Figure 1 shows average RF values during each game for each of the 5 participants in the experimental group. RF values for Mary, Sarah, and Adam were lower at the end of the VAR phase than the initial PROB1 phase, indicating that variability increased when it was reinforced. For Joe, there was less of a clear trend. Joe's RF values increased toward the end of the PROB1 phase, and decreased during VAR, but overall values were similar. Greg's RF values increased during PROB1 and remained high during the VAR phase, but then decreased sharply during the subsequent PROB2 condition. RF values were lower for all participants at the end of the PROB2 phase than at the end of PROB1, indicating that the effects of VAR contingencies were maintained after the variability requirement was removed.

Figure 2 shows RF values across games for participants in the adult control group. As with most of the experimental group, RF values for all 5 participants were lower at the end of the VAR phase than at the end of PROB1, indicating again that reinforcement led to increased variability. For 4 of 5 participants (Cindy, Peter, Jenny, and Rich), RF values were lower during PROB2 than PROB1, as was the case for the experimental participants.

Figure 3 shows the average RF values across games for participants in the child control group. As with the other two groups, RF values for Fred, Derek, and Steve were lower at the end of VAR than at the end of PROB1 and were lower at the end of PROB2 than at the end of PROB1, indicating that reinforcement again increased and maintained variability. For Alice, the data were not consistent with the other 3 participants. There was a rise in RF values during PROB1, then a sharp decrease at the end of that phase. Her RF values then remained at consistently low levels throughout the VAR and PROB2 phases.

Statistical comparisons of the three groups were consistent with the trends just described although, as noted above, there were some individual variations. For these analyses, average RF values were computed based on the last 150 trials under PROB1, VAR, and PROB2 phases. We observed significant group effects, $F(2, 11) = 4.52$, $p < .05$, and contingency effects, $F(2, 22) = 10.74$, $p < .001$ (see Figure 4). Individuals with autism were significantly less variable overall than the adult control group (Newman–Keuls, $p < .05$) but did not differ from the child controls. Most important, all groups responded more variably under VAR and PROB2 schedules than under PROB1 (Newman–Keuls, $p < .01$).

Levels of variability were also compared using U values calculated across the last 150 trials of each condition. (U-value calculations require large amounts of data and therefore cannot be shown for individual games.) In this case, higher values indicate higher variability. The group effect approached significance, $F(2, 11) = 3.41$, $p = .07$, and, most important, the contingency effect was significant, $F(2, 22) = 14.89$, $p < .001$ (Figure 5). U values for all groups under VAR and PROB2 were significantly higher than under PROB1 (Newman–Keuls, $p < .01$). Thus, the U-value analysis was consistent with the RF analyses in showing
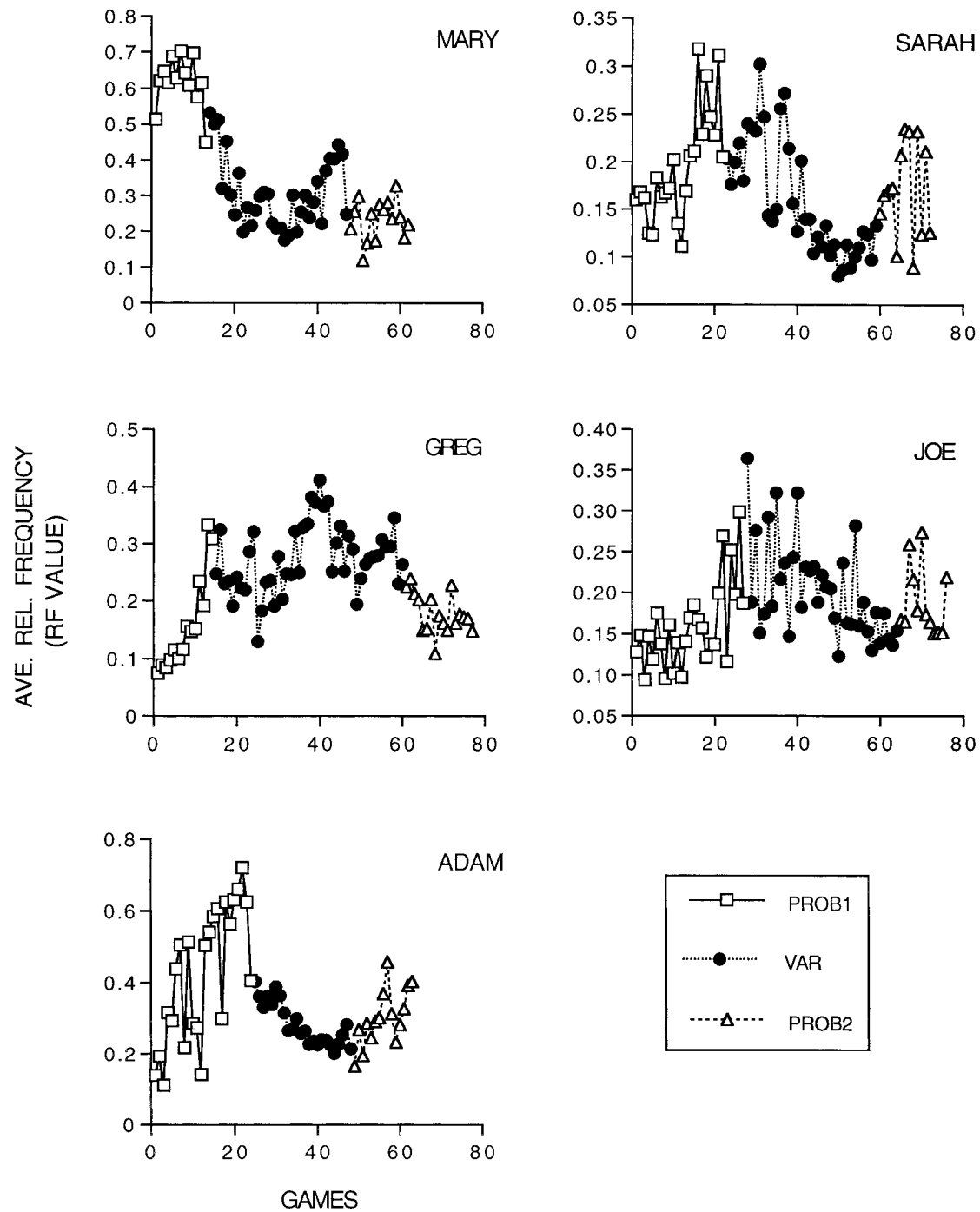
Figure 1.   Average RF values of sequences in each game played for the 5 participants with autism. The lower the RF value, the greater the variability. Reinforcement depended upon high variability in the VAR phase and was independent of variability in the two PROB phases.
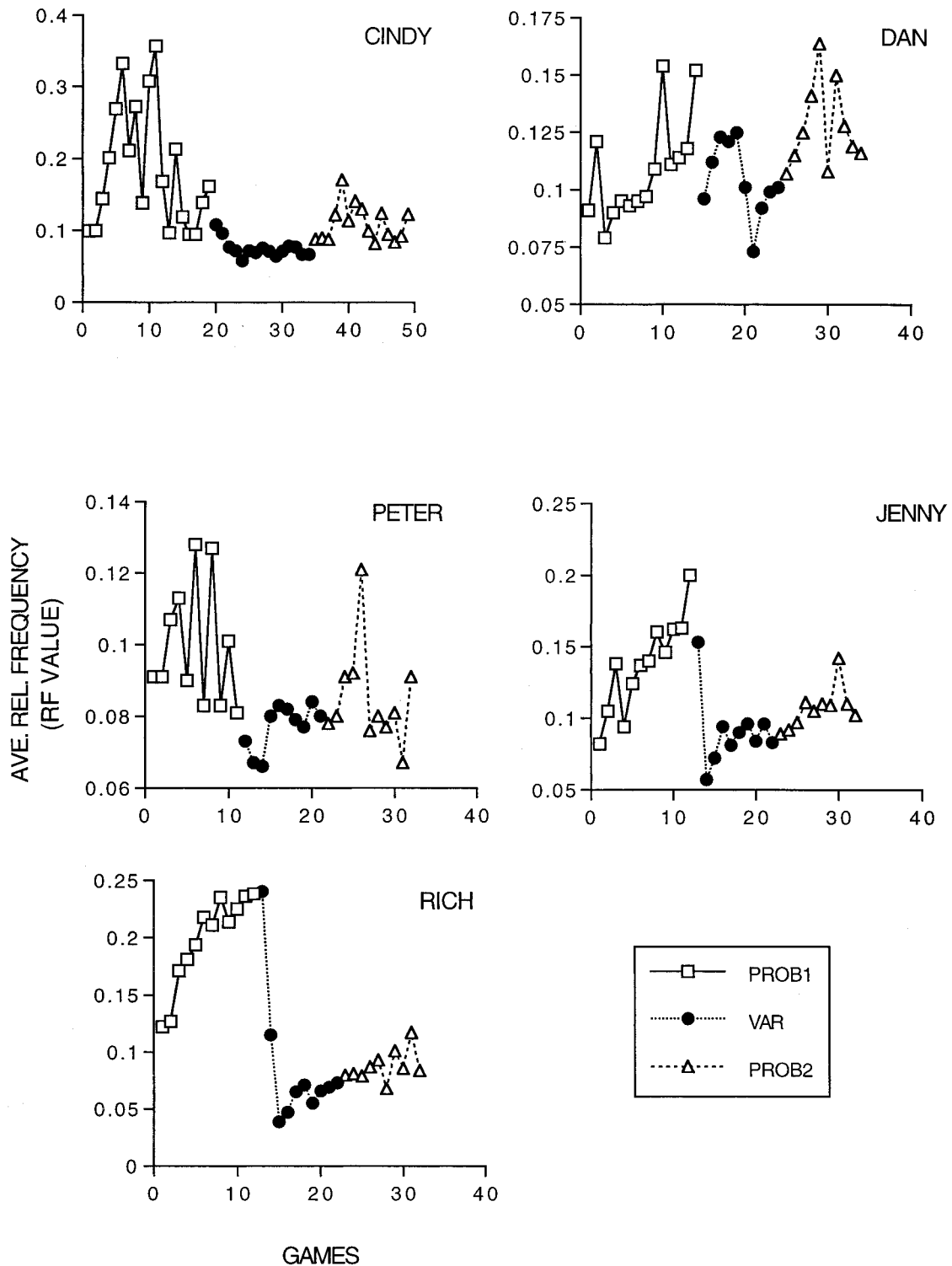
Figure 2. Average RF values of sequences in each game played for the 5 adult control participants. The lower the RF value, the greater the variability. Reinforcement depended upon high variability in the VAR phase and was independent of variability in the two PROB phases.
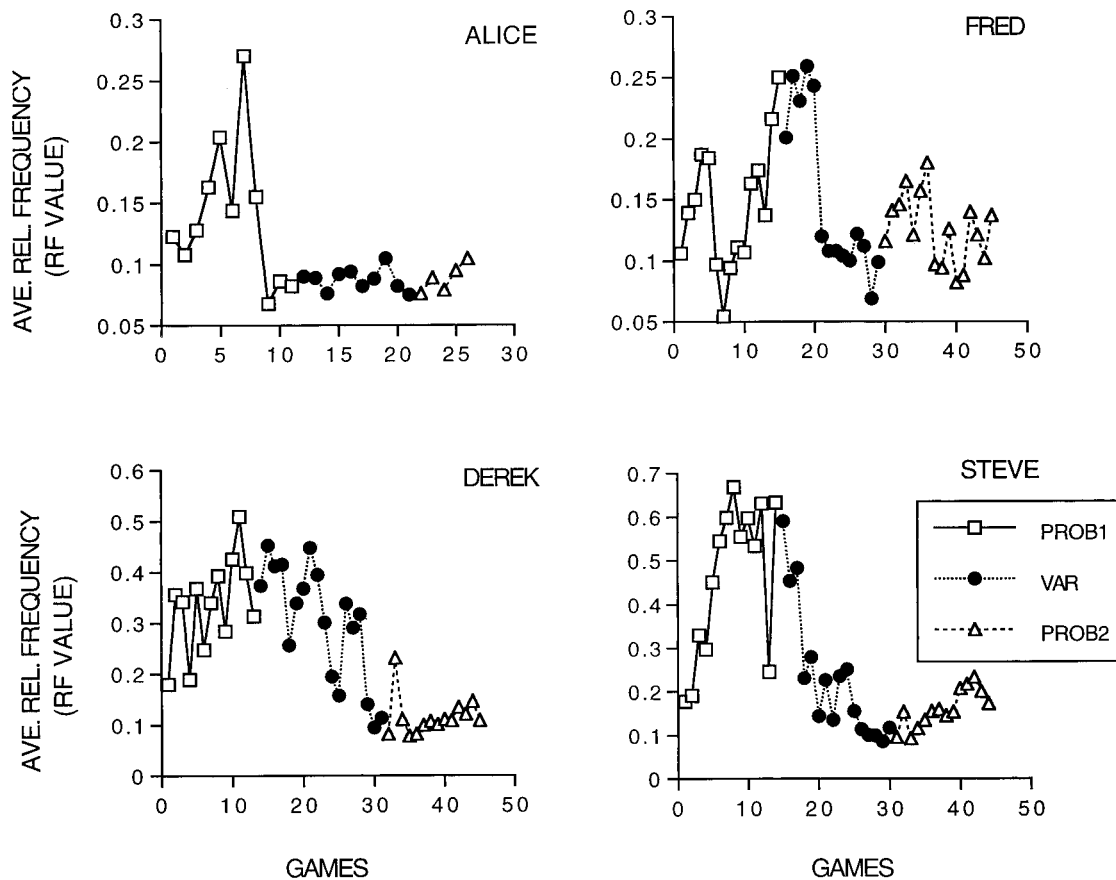
Figure 3.   Average RF values of sequences in each game played for the 4 child control participants. The lower the RF value, the greater the variability. Reinforcement depended upon high variability in the VAR phase and was independent of variability in the two PROB phases.

that, for all groups, variability increased when it was reinforced and remained high after reinforcement was no longer contingent on high levels of variability.

The participants with autism experienced 700 trials under VAR, whereas the control participants experienced only 300 trials. To ensure that this difference did not contribute significantly to the results, one additional analysis was performed which used the 150th to 300th trials under VAR for all participants. The same statistical effects were observed as just reported: Most important, variability increased significantly in VAR for all groups.

DISCUSSION

Control by reinforcement of variability is similar to reinforcement of other response dimensions, such as response rate and force (Goetz & Baer, 1973; Machado, 1989; Maloney & Hopkins, 1973; Neuringer, 1986; Stokes, 1999). The present study used an ABA design in which rewards were initially presented without regard to response variation (PROB1), following which reinforcement depended on variations of sequences of left and right button presses (VAR), and finally a return to the initial contingencies (PROB2). Performance by participants with autism was compared with that of adult and
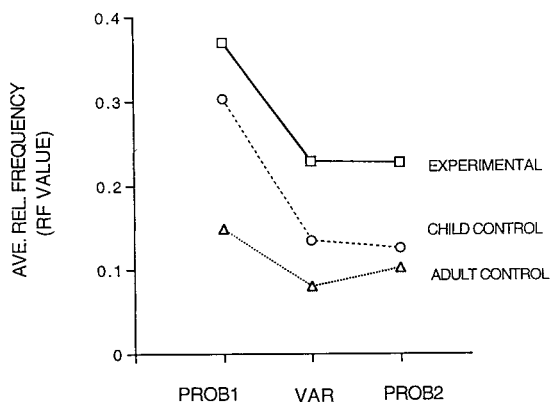
Figure 4. Average relative frequencies for each of the groups in each of the phases. Averages were computed for each participant across the last 150 trials in each phase, and then group averages were computed. The lower the RF value, the greater the variability.

child control groups. The results were, first, that the percentile reinforcement contingencies in VAR engendered higher levels of variability than the initial baseline (PROB1) for participants with autism as well as for the controls. Second, high variability continued in all groups during the PROB2 phase, after discontinuation of the variability contingency. Third, participants with autism responded less variably overall than adult controls.

These data show that behavioral variability can be reinforced in individuals with autism and directly contradict the hypothesis that such individuals are unable to vary (e.g., Boucher, 1977). The low response variability described by Mullins and Rincover (1985), Boucher (1977), and Baron-Cohen (1992) may reflect the absence of effective reinforcement contingencies rather than immutable participant characteristics. That adult control participants in the present study responded more variably than individuals with autism is consistent with previous reports (Baron-Cohen, 1992; Boucher, 1977; Frith, 1972). Caution is needed, however, in interpreting this difference, because the groups differed in many ways (e.g., chronological age and intellectual abilities). (We used two

control groups in order to compare the participants with autism along both of these dimensions.) Furthermore, participants with autism had coexisting disorders and were maintained on medications that might have affected variability. Furthermore, because of the nature of the populations studied, different numbers of responses per game and games per session as well as qualitatively different reinforcers were used across the three groups. These inconsistencies in protocol were required to successfully reinforce variability in each of the participants.

The present results are important because variability may facilitate acquisition of new behaviors and behavior sequences. For example, Grunow and Neuringer (unpublished data) provided reinforcement to four groups of rats for four different levels of sequence variation. Animals that responded most variably learned to emit a new, difficult-to-learn target sequence; animals that emitted little variation never learned; and intermediate levels of variability supported intermediate learning (see also Neuringer, 1993; Neuringer, Deiss, & Olson, 2000). One interpretation of these results is that reinforcement of variability widens response repertoires, thereby providing a baseline from which reinforcers can select new responses. Reinforcement of variability could similarly increase the response repertoires of individuals with autism and thereby facilitate learning. As an example, an individual who regularly repeats a single phrase might receive reinforcement contingent on variable vocalizations; such variability might help to engender spontaneity and conversational skills, aspects of language that have traditionally been difficult to teach to individuals with autism (Carr & Kologinsky, 1983; Lovaas, 1968). Stated differently, direct reinforcement of variations might provide the opportunity for natural reinforcers to select appropriate, functional behaviors.

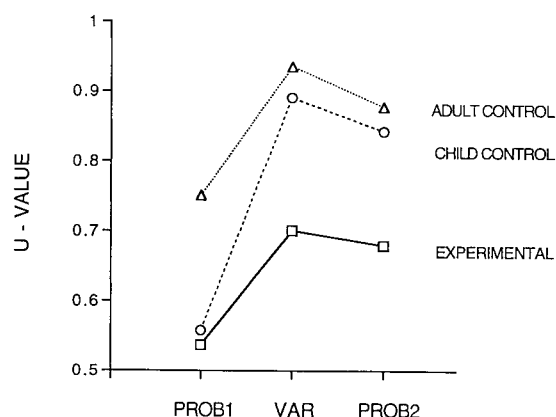Reinforcement of variability could in-

Figure 5.   Average *U* values for each of the groups in each of the phases. Averages were computed for each participant across the last 150 trials in each phase, and then group averages were computed. The higher the *U* value, the greater the variability.

crease normal behavior in another way. Animal models show that behavioral variability is controlled by discriminative stimuli, with appropriately high variability in one stimulus and repetitions in another (Denney & Neuringer, 1998). Such stimulus control might enable the individual with autism to behave more appropriately in natural environments. Normal behavior manifests differing levels of behavioral variability, which are controlled by discriminative stimuli and reinforcement contingencies.

Behaving variably is incompatible with the stereotypies and repetitive responding commonly associated with autism. Therefore one goal of therapy directed at modifying the behavior of individuals with autism is to increase variability. There are many sources of variability other than direct reinforcement (Balsam, Deich, Ohyama, & Stokes, 1998; Segal, 1972). For example, previous studies using DRO and DRL schedules to discourage stereotypies have at the same time engendered increased behavioral variation (Gunter et al., 1984; Handen et al., 1984; Kennedy & Haring, 1993; Smith, 1987; Wong et al., 1991). Another method is noncontingent reinforcement (NCR), in which

reinforcers that maintain abnormal behaviors are provided noncontingently. The result is to weaken the relations between the abnormal response and the reinforcer, thereby decreasing the frequency of the abnormal behavior (Lalli, Casey, & Kates, 1997). Increased levels of behavioral variability are also produced by withholding all reinforcement (extinction; Balsam et al., 1998) and by slowing responding (Baddeley, 1966; Morris, 1987; Neuringer, 1991). However, direct reinforcement of variations may have important advantages over a schedule that relies exclusively on extinguishing or slowing the repeated behavior.

For example, when extinction was compared to direct reinforcement of variations in rats (Neuringer, Kornell, & Olufs, unpublished data), (a) both procedures increased variability, (b) direct reinforcement engendered higher variability than extinction did, and (c) extinction effects were short-lived (because all responding was extinguished), whereas reinforced variability could be maintained indefinitely. Thus, direct reinforcement is at least as effective as withholding reinforcement. Furthermore, extinction and many of the other commonly used procedures often result in problematic side effects. For example, DRO, DRL, and NCR contingencies may generate superstitious behaviors. Extinction, DRL, and NCR may cause aggressive outbursts (e.g., Vollmer, Ringdahl, Roane, & Marcus, 1997). Direct reinforcement of variability provides the advantages of increased variations without these disadvantages.

We conclude with two methodological considerations. First, because variability was maintained despite a return to baseline conditions, there is a question of whether variability was in fact reinforced. As indicated above, many previous studies have documented the reinforcement-of-variability effect, and some have shown that in human participants, following a period of reinforce-

ment, variability tends to be maintained despite return to variability-independent contingencies (e.g., Saldana & Neuringer, 1998). Furthermore, in the present study, different participants began at different times and experienced differing numbers of reinforcements. We conclude, therefore, that variability was in fact reinforced in both control participants and those with autism, but this conclusion should be tested further.

Second, the percentile reinforcement schedule used in the present research could be problematic in natural settings. It may be difficult to define, record, and analyze naturally occurring behaviors in real time, and percentile reinforcement contingencies are difficult to maintain without the aid of a computer. In a related procedure, Duker and van Lent (1991) rewarded individuals with severe mental retardation for increased variety of communicative gestures. Relative frequencies of an individual's gestures were calculated after each session, and the experimenters ranked these. The criterion for the next session was set so that the most frequently occurring responses were not reinforced and less frequent gestures were. Such a discrete-session format may be useful to set the criteria for reinforcement under a percentile reinforcement schedule.

Alternatively, contingencies other than percentile schedules could be employed. For example, Pryor et al. (1969) reinforced novel behaviors in porpoises by judging whether the particular behavior had been previously observed. Similarly, Holman et al. (1977) reinforced novel drawings and block constructions in children. Both of these examples show that variability can be increased by reinforcing "do something different," and this can be done in a way similar to the shaping of other response dimensions. Alternatively, lag contingencies can be used, under which reinforcement depends upon the current response differing from the last *n* responses, with *n* specified by the lag (Page & Neurin-

ger, 1985). Thus, for example, a Lag 3 contingency requires the current response to differ from the last three responses, with the window of responses moving with each response. Although variability increases with the value of the lag, highly variable responding can be obtained even with relatively low values (Page & Neuringer, 1985). Perhaps the most simple method is to reinforce nonrepetitions. Bryant and Church (1974) observed that differentially reinforcing alternations (between two operanda) caused rats to vary their response sequences (see also Machado, 1992, 1997). Thus, basing reinforcement simply on "not doing what was just done" (as would be the case under a Lag 1 contingency) might suffice in some cases to increase overall variability. When alternating between two behaviors results, as is sometimes found (Machado, 1992), then the contingency could be changed to a Lag 2 or higher contingency.

If one goal of treatment is to increase behavioral variability, direct reinforcement of successive approximations to this goal may be an effective procedure. Reinforcement of variability will, we predict, prove to be useful for modifying the behavior of individuals with autism.

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STUDY QUESTIONS

1. How might stereotypic behaviors exhibited by individuals with autism result in the loss of reinforcement?

2. What are the general features of percentile schedules of reinforcement?

3. Describe the procedures used when the VAR contingencies were in effect. How was the contingency different during the PROB phases?

4. What type of experimental design was used? Given that the authors expected increases in variability to be maintained, what alternative design may have afforded a greater degree of experimental control?

5. What specific measures were used to evaluate sequence variability, and what features of responding are characterized by these measures?

6. Summarize the main findings.

7. What are the implications of the present results with respect to the training of adaptive skills in individuals with autism?

8. What is the practical limitation in implementing percentile schedules in natural settings? What simplified alternative do the authors suggest?

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