Reinforcement, Stereotypy, and Rule Discovery

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The effects of reinforced pretraining on subsequent rule discovery were examined with college students as subjects. Levels of behavioral stereotypy observed during reinforced and non-contingent pretraining were compared. During pretraining subjects received reinforcement if they pressed two keys in a particular sequence. During the problem session pressing each key four times was a necessary condition for reinforcement, but each problem had additional different requirements for reinforcement. Subjects were asked to solve the problems by discovering the rule that determined whether or not they received reinforcement. Levels of stereotyped responding during pretraining were equivalent for contingently and non-contingently trained subjects. During the problem session contingently pretrained, non-contingently pretrained, and naive subjects required equal numbers of trials to solve problems and solved the same number of problems. The results suggest that behavioral stereotypy observed in this experimental preparation may be due to repeated exposure to the task. Differences between the results observed in this study and that of Schwartz (1982) and implications for the use of reinforcement procedures in applied settings are discussed.

Reinforcement is not a completely benign behavioral process. For example, it may inadvertently produce elicited or emotional effects that interfere with the occurrence of the target response, produce inappropriate behavior, or suppress other desirable behavior as the target behavior increases in frequency (Balsam & Bondy, 1983). It obviously may be used to increase socially undesirable behavior. Some argue that when used arbitrarily it may interfere with the effects of the natural consequences of behavior (Lepper, Greene & Nisbett, 1973). Schwartz (1982) has reported another possible negative effect of reinforcement procedures: it may produce

stereotyped behavior that interferes with rule discovery.

In Schwartz's study college students learned to guide a light through a 5 by 5 matrix of lamps. Different combinations of pushes on two buttons caused the light to take different routes through the matrix. A total of 70 routes were possible, given the restrictions that had been placed on light movements.

In one of Schwartz's experiments the subjects were told that if they pressed the keys in an appropriate manner, they would earn points and would be paid two cents for each point accumulated. Subjects showed what Schwartz termed stereotypy. He defined stereotypy in two ways—the use of relatively few of the 70 possible sequences that would produce reinforcement and the preponderant use of a dominant (most frequent over all trials) response sequence. By the last 3 of 9 blocks of 50 trials each, all four subjects were

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using one (the dominant) sequence of key presses on over 80% of the trials in each block. The number of different sequences used in the last 3 blocks had dropped below 10. Schwartz concluded that the source of behavioral stereotypy was reinforcement.

In a series of subsequent experiments Schwartz identified several apparent problems produced by reinforcement. One of the most serious claims was that reinforcement interfered with subsequent rule discovery. In these subsequent studies, Schwartz divided the subjects into those who received reinforced pretraining and those who did not. Each pretrained subject received 1,000 trials spaced over two successive days in a condition that limited the number of different response sequences that were reinforced. Each successful trial earned the subject one point worth one cent.

Subjects in the pretrained and naive groups were then given a single session in which several different problems were presented to the subject. A problem required a particular sequence of button pushes to earn a point. Subjects were given 300 trials within which to guess the "rule" that was then in effect. After an accurate guess (or 300 trials) the next problem began. Within pretrained and naive groups, different reinforcement conditions were examined for the problems session: some subjects received points for successful trials, some received a dollar for guessing the rule, some received both, and some received neither.

Naive subjects correctly described the contingencies significantly more often than pretrained subjects whenever monetary points for successful trials were given. Pretrained subjects also needed significantly more trials in all reward conditions than naive subjects. Naive subjects generated more hypotheses per trial than pretrained subjects in the conditions when points were given and in the no reward condition.

The negative effects of such a simple contingency on rule generation would be worth serious concern if they were robust.

Many educational programs have as their goal fostering problem solving. For example, a teacher might provide stars or stickers for the completion of specific math problems with the hope that the child will abstract certain mathematical rules that are applicable across instances. If a history with such consequences greatly reduced problem solving skills or rule derivation, this would seem to argue strongly against any such use of explicit contingencies in educational settings.

Schwartz attributed the poorer performance of pretrained subjects to the previous reinforced experience with a task on the same apparatus. In principle, excessive stereotypy might well interfere with rule discovery because it might interfere with making contact with changed contingencies. But the "reinforcement" processes involved in Schwartz's study were never directly tested, and were limited to the presence or absence of monetary consequences that were directly instructed by the experimenter. During pretraining the "reinforcement" subjects had experienced 1,000 trials of exposure to a task that is quickly mastered. It is not clear whether a) the stereotypy was due to reinforcement, instructions regarding reinforcement, or simply to extensive exposure, and b) whether the negative effects of consequences on rule generation were due to contingent consequences, instructions regarding these consequences, mere exposure, or non-contingent presentation of "consequences." If stereotypy and subsequent difficulties in problem solving are not due to monetary contingencies per se, but to exposure to the task, then a contingent and a non-contingent reinforcement condition in pretraining should have similar effects. The present study replicated Schwartz's method, but with the addition of controls for the effects of extended pretraining to see if reinforcement per se was responsible for the results seen.

METHOD

Subjects

The subjects were 24 undergraduate stu-

dents recruited by bulletin board notices and flyers for paid participation in the experiment. All subjects were told that they would receive a minimum of \$3.60 per hour for their work, and that they were free to withdraw at any time and be paid for their time. No subjects chose to withdraw.

Apparatus

A 2.6 m X 2.4 m room contained a table and a chair. A computer monitor, an intercom, and a response console were placed on the table. The response console consisted of two normally-open, momentary contact button switches mounted on a box. The monitor and switches were connected to a microcomputer in an adjoining room.

The experimental apparatus was similar to that used by Schwartz (1982). During experimental sessions a five by five matrix of 4.0 by 3.5 cm rectangles was projected on the screen. A small plus sign was located in the upper, left rectangle. The apparatus was configured so that pushing the left button moved the plus sign into the rectangle below its previous position. Pushing the right button moved the plus sign to the rectangle to the right of its previous position. As in Schwartz's study, pushing each button four times moved the plus sign from the upper left rectangle to the lower right rectangle. If either button was pushed a fifth time before the plus sign was moved to the target rectangle, the screen went blank and the intertrial interval began.

Procedure

The subjects were randomly divided into three groups. One pretrained group received a point worth one cent for each correct response during pretraining (the same value as used by Schwartz, 1983). In all cases this amount was greater than what would have been earned by the hourly rate. A second group received non-contingent monetary consequences. These subjects were told that they would be paid on an hourly basis for working on the pretraining task, but these subjects were actually yoked to subjects in the reinforced pre-

training group and received the same payment for pretraining as the subject to whom they were yoked. (In all cases this payment exceeded the hourly wage earnings.) Immediately prior to the problem-solving session all pretrained subjects were told how much they would be paid for pretraining. This procedure assured that subjects in both groups had received the same amount of money during pretraining. A third group of students received no pretraining and participated in the problem-solving session only.

Pretraining. Subjects were shown the apparatus and told that they could earn points by pressing the buttons in an appropriate manner. They were told that the buttons would work whenever the 5 X 5 matrix was visible on the screen and that if they pressed the buttons in the correct way a message would appear on the screen telling them that they had earned a point. No information was given concerning what constituted a correct response or about the purpose of the 5 X 5 matrix. In accord with Schwartz's procedure, during pretraining a correct response consisted of any series of button presses that closed each switch four times and began with two presses on the left button. The intertrial interval was 1 sec in duration. If a correct response had been made a message indicating that a point had been earned and the cumulative total of points earned in the session was displayed on the screen during the intertrial interval. If an incorrect response had been made the screen was blank during the interval.

The following instructions were read to all pretrained subjects:

This is an experiment in human learning. We are examining the responses people make to a learning task. It is not an intelligence test or a psychological test of any kind. If you press the buttons in the correct manner, you will earn a point. A message will appear on the screen telling you how many points you have earned.

If you press the buttons in an incorrect manner, the screen will go black. We want you to make as many correct responses as possible. If there are any problems or you want to take a break call me on the intercom.

Subjects in the contingent pretraining condition were given these additional

instructions: "You will be paid one cent for each correct response. Regardless of your performance, you will be paid a minimum of \$3.60 per hour for your participation." Subjects who received the non-contingent pretraining were given these additional instructions: "You will be paid \$3.60 per hour for this work."

Subjects were then given an opportunity to ask questions. These questions were answered by reading the relevant portion of the instructions again.

Subjects received a total of 1000 pretraining trials with 500 trials given on each of two successive days. Trials were presented in blocks of 50 with a 10 sec pause between blocks.

Problem solving. The pretrained subjects were given a problem-solving session on the day immediately following the completion of pretraining. These subjects were given the following instructions:

So far you have earned [amount]. In this session you will be given a series of problems using the same apparatus as you used in the previous two sessions. In each problem the requirements for earning points will be different. We want you to discover what is required for earning points in each problem. At the end of every 10 trials you will be given a chance to describe the requirements for earning points. If you think you know what is required, summon the experimenter by using the intercom. If you don't want to guess the solution, press both buttons at the same time for more experience with the same problem. Your description of the requirements for earning points must be exact and thorough. The description must include all possible correct ways to earn points and must exclude all wrong responses. You will be paid one cent for each point earned and one dollar for each problem solved.

Subjects in the naive group were given the following instructions:

This is an experiment in human learning. We are examining the responses people make to a learning task. It is not an intelligence test or a psychological test of any kind. If you press the buttons in the correct manner, you will earn a point. A message will appear on the screen telling you how many points you have earned. If you press the buttons in an incorrect manner, the screen will go black.

The naive subjects were then given the same instructions regarding the problem-solving session omitting reference to previous sessions and money earned.

Subjects in all groups were given a chance to ask questions. Questions were answered by reading the relevant portion of the instructions again.

All subjects received four problems in the same order (identical to those used by Schwartz and presented in the same order). In each problem, four responses on each of two buttons were necessary but not sufficient for earning a point. The first problem required that a sequence begin by pushing the right button. The second problem required that a sequence be different from either of the previous two. The third problem required the movement of the cursor through a particular rectangle of the 5 X 5 grid, reached by any initial combination of two left and one right button pushes. The fourth problem required that a sequence begin with pressing the left button.

Subjects worked on the problems in 10-trial blocks. At the end of each block they could initiate a new 10-trial block with the same problem or summon the experimenter to make a guess about the solution. Each time the subjects summoned the experimenter an audio tape recorder was used to record the subject's guess. The experimenter used written criteria to decide whether or not the subject's guess was a solution of the problem. The criteria did not require a restatement of the general conditions common to all problems and pretraining (four and no more than four presses on each button). A correct solution did require a description of the contingencies that included all possible correct response sequences and excluded all incorrect sequences. If the guess was correct, the experimenter told them so and initiated the first block of trials on the next problem. If the guess was incorrect, the experimenter told the subjects to continue. If the subjects failed to solve the problem in 30 blocks the subject was told that there would be no further work on that problem, and work on the next problem was begun.

Reliability checking. A sample of thirty-two of the subjects' attempted problem solutions was drawn from the available audio recordings. When incorrect guesses

were included in the sample these were always the last guess for that problem or the last guess preceding a correct solution. (It was assumed that there would be

progress toward the solution and the last incorrect guess would be most similar to the correct solution.) A separate rating tape was prepared for each problem. The sam-

Fig. 1. Individual measures of stereotypical responding by 50-trial blocks for all subjects in the Contingent Pretraining and Hourly Pay Pretraining groups. The filled marks connected by solid lines represent the number of times the dominant pattern occurred. The open marks connected by dashed lines indicate the number of different patterns shown.

ples were placed on the tape in random order. The reliability judges were two psychology graduate students with experience in research programs. They were naive to the purposes of the present study. They were given experience with the experimental problems and received a copy of the written criteria for correct solutions that were used by the experimenter. Each reliability judge worked independently to arrive at his/her ratings. Both judges agreed with the ratings of the primary experimenter on 86% of the audio samples.

RESULTS

Pretraining

During pretraining both the contingent and non-contingent groups showed high and nearly identical rates of stereotypy. Following Schwartz's procedure, stereotypy was evaluated in two ways. The most frequent sequence used by the subject dur-

ing pretraining was called the "dominant" response. The number of trials in which the dominant response occurred was determined for each 50-trial block and for the entire pretraining period. In addition, stereotypy was evaluated by examining the number of different sequences that occurred during the 50-trial pretraining blocks of the fifteen that could produce points during pretraining.

Individual response patterns (see Figure 1) reveal that some subjects showed highly stereotyped responding (e.g., Subjects 2, 6, 7, 8, 13, 15, 16). All but 6 subjects (1, 4, 5, 9, 11, & 14) emitted their dominant sequence on more than 50% of the pretraining trials. Overall, subjects in the hourly pay pretraining group used their dominant sequence on 60.8% of the trials. The contingent pretraining group used their dominant sequence on 65.0% of the trials. The frequency of the dominant response in each 50-trial block was analyzed using a 2

Fig. 2. Group measures of stereotypical responding by 50-trial blocks for the Contingent Pretraining and Hourly Pay Pretraining groups. The filled marks represent the average number of times the dominant pattern occurred. The open marks indicate the average number of different patterns shown.

X 20 repeated measures analysis of variance design. The variables were type of pretraining (contingent or hourly) and 50-trial blocks of pretraining. This analysis yielded no statistically significant effects (F 's < 1.01).

The other measure of stereotypy used by Schwartz was the number of different sequences used within any fifty-trial block. The subjects who received contingent pretraining used an average of 6.29 different sequences in each block while those who received hourly pay used an average of 6.34 different sequences. The data regarding the number of different patterns in the pretraining blocks were analyzed using the same 2 X 20 repeated measures design analysis of variance. A significant effect for blocks of pretraining was found, $F(19,266)=7.27$, $p<.001$. This indicates that as pretraining proceeded, the number of different trials in a block decreased. That is, behavioral stereotypy increased as a function of length of pretraining. The effects of type of pretraining and all interactions were insignificant (F 's $(1,14)<1$). The average values for both measures of stereotypy for the two pretrained groups are presented graphically in Figure 2. Thus, pretrained subjects became more stereotyped in their responses after the initial blocks, regardless of the reinforcement contingency in force.

Accuracy of responding was also statistically equivalent. Subjects who received contingent pretraining made an average of 933.9 correct responses while those who received non-contingent pretraining made an average of 940.3 correct responses, $F(1,14)<1$.

Problem Session

The performance in the problem session was virtually identical for all three groups. The mean number of problems solved were as follows: contingent pretraining, 3.25; non-contingent pretraining, 3.375; and no pretraining, 3.375. A one-way analysis of variance on the number of problems solved yielded a nonsignificant result $F(2,21)<1$. The three groups of subjects also required essentially equal numbers of 10-

trial blocks in the problem-solving session (contingent pretraining, 51.6; non-contingent pretraining, 50.0; no pretraining, 55.25). Again, an analysis of variance gave a nonsignificant result.

A more detailed analysis of the subjects' performance on the problem-solving task shows further similarity in the performance of the three groups of subjects. Virtually all of the variability between subjects came from different performances on problems 2 and 3. All subjects solved problem 4 correctly. Only one subject (from the contingent pretraining group) missed the first problem. Four subjects from each group missed problem 2, and one subject from each group missed problem 3.

The subjects in the three different groups earned statistically equivalent numbers of points on the individual trials of the problem session. The means were as follows: contingent pretraining, 329; hourly pretraining, 279.25; naive, 318, $F(2,21)<1$. Differences in money earned in the problem session (1 cent for each point and a dollar for each problem solved) were again statistically insignificant (means were contingent pretraining, \$6.54; non-contingent pretraining, \$6.17; and \$6.56; $F(2,21)<1$).

Schwartz (1982) reported that reinforced pretraining resulted in an increased number of trials required for the generation of new hypotheses. In this experiment all three groups of subjects generated hypotheses at roughly equivalent rates. Means for trials per hypothesis were as follows: contingent pretraining, 53.6; hourly pretraining, 52.55; naive, 52.84; $F(2,21)<1$.

DISCUSSION

Schwartz argues on the basis of his set of experiments that reinforced pretraining produces stereotyped responding (1982, p. 49) and interferes with later rule discovery (problem solving). Schwartz does not clearly state that the behavioral stereotypy produced by reinforcement is the factor that interferes with rule discovery. This inference is, however, implied by the title of the article, "Reinforcement-induced behavioral stereotypy: How not to teach people to discover rules." The variable

"behavioral stereotypy" was not manipulated, however. The independent variable was reinforced pretraining versus no pretraining. Reinforcement, itself, was also not independently manipulated; there was no "unreinforced" pretraining with which to compare it.

The negative effects reported by Schwartz may have not have been due to reinforcement, especially since proper controls were not used. Schwartz recognizes this possibility in his discussion. He points out that "...reinforcement per se may have been incidental to the effects observed. Some other device for inducing repetition may have produced the same effects" (p. 50). The results of the present study supports this concern.

Pretrained subjects in the present experiment showed lower levels of stereotypy than those of Schwartz. Ninety-five percent of his subjects showed their dominant sequence on more than two-thirds of all trials. Fifty-six percent of the subjects in this study showed their dominant response that often. Extreme forms of stereotypy could quite likely lead to interference with rule discovery because contact with the contingencies could be limited. Thus, the differences seen in rule discovery in our replication could be due to these lower levels of stereotypy. It is not clear why the two experiments achieved different outcomes in this area, but apparently stereotypy is not always as characteristic of this procedure as Schwartz believed.

Nevertheless, because stereotyped responding clearly did occur, the *degree* to which this was produced by contingent monetary consequences can be examined. Pretrained subjects used an average of 6.3 different response sequences per 50-trial block while 15 different response sequences could earn reinforcement. However, non-contingent pretraining resulted in levels of behavioral stereotypy equal to that observed during reinforced pretraining. Our data provide no basis for the view that reinforcement was responsible for stereotypy in this task. In addition, no differences were observed in the level of rule discovery among the groups.

It could be argued that the lack of a difference between the non-contingent and reinforced pretraining groups was produced by the reinforcing effects of points per se, as opposed to points worth money. Viewed in this fashion, both groups received reinforcement and thus it is not surprising that both showed the same results. If viewed this way, however, Schwartz's more general concern must fall. The points simply provided feedback on successful task completion, and it seems difficult to argue that the feedback provided by the successful completion of a task interferes with rule discovery about that task. To return to the example used earlier of teaching math, it could be claimed that the feedback provided by arriving at an answer in a math problem that checks out is itself reinforcing. From a behavioral point of view this seems likely. But it would be absurd to argue that solving math problems correctly interferes with the discovery of mathematical rules about how to solve math problems correctly.

Part of the difficulty in interpreting Schwartz's study is his lack of clarity about what he means by "reinforcement." At several points in his discussion, Schwartz uses "reinforcement" only to refer only to money received contingently, and not to the functional effects of the wide range of consequences that were available in his experiments.

In discussing the apparent negative effects of reinforcement in his study Schwartz attributes these negative effects to "trivial sums of money" (1982, p. 57), but the effects were clearly moderated by instructional and social control. For example, Schwartz's fourth experiment (1982) involved rule discovery, but the subjects were told at the beginning of the experiment that they were to discover the rule that determined whether or not they received reinforcement. Subjects earned monetary reinforcement by performing "correct" sequences. With these instructions, the subjects showed variety in responding that seemed to indicate that they were testing hypotheses. Subjects also

stated rule solutions, when the monetary earnings could be maximized by refusing to state rules and continuing to make correct responses. This experiment produced no evidence of behavioral stereotypy or negative effects of reinforcement on rule discovery. In the discussion of his fourth experiment he makes the following argument:

it is possible that reinforcement contingencies did not impede rule discovery in Experiment 4 because the contingencies never gained control of behavior. Consider the subject as he or she has just begun the task. By ignoring the request of the experimenter and doggedly repeating a given sequence, the subject might earn four or five dollars in an hour. But the price for this windfall is the wrath of the experimenter. In contrast, the subject can do what the experimenter has asked, avoiding his wrath, and still earn a fair sum of money. Given what one might imagine to be the relative values of these incompatible payoffs, it is quite possible that for subjects in the experiment, the reinforcement contingency was simply irrelevant, except as a source of information about which sequences worked and which did not. If so, Experiment 4 hardly constitutes evidence that reinforcement contingencies do not interfere with problem solving. Rather, it constitutes evidence that reinforcement contingencies do not always control behavior. (1982, pp. 34-35)

In this analysis, Schwartz attributes the failure of "reinforcement" to disrupt rule discovery to the overlapping effect of the experimenters' approval. Money is discussed as a reinforcer, but the approval or "wrath" of the experimenter is not viewed as contingent reinforcement or punishment. Schwartz discusses "incompatible payoffs," but not concurrent contingencies. There is a great deal of complexity to these concurrent contingencies. The relevant consequences are instructed verbally, and involve different responses (pennies and points for button pushing, dollars for rules, and possible social approval or disapproval for compliance). While it is difficult to be certain of the factors producing his results, the arrangement used was far too complex to justify the sweeping claims about reinforcement that Schwartz makes.

For example, it could be argued that the behavior of the subjects in Schwartz's Experiment 4 did come under the control of the most powerful contingencies present, the social contingencies mediated by

the experimenter, in spite of the competing monetary contingencies. These social reinforcers apparently did not disrupt rule discovery. Schwartz can argue that reinforcement interferes with rule discovery only if such things as task feedback or the "wrath of the experimenter" (Schwartz, 1982, pp. 34-35) are not thought of in reinforcement terms.

This study replicated one portion of Schwartz's Experiment 7 — the reward condition in which subjects received one cent for each correct response and one dollar for each correct statement of the rule that described the contingency condition for a problem. This reward condition was chosen for replication for two reasons. First, in this reward condition Schwartz found clear differences between pretrained and naive subjects on two measures—number of problems solved and number of trials required in the problem solving session. Second, this reward condition seems to be most relevant to the use of contingencies in applied settings. Often correct responses on single trials are reinforced in programs designed to establish a more general skill.

Our results indicated no differences in the performance of naive and pretrained subjects on any of the measures taken in the problem-solving session. In comparison to Schwartz's subjects, the pretrained subjects in this experiment solved more problems, and the naive subjects solved fewer problems. There were, however, two minor differences in procedure between the two studies.

First, ethical considerations did not allow us to exactly duplicate the "reinforced" pretraining that Schwartz used. The institutional ethics committee required that all subjects be guaranteed fair compensation for their time regardless of their performance and that subjects be allowed to withdraw from the experiment without penalty. Our subjects were guaranteed a basic hourly wage regardless of performance. The penny per point reinforcement contingency may thus not have been as salient as it was for Schwartz's subjects. It should be noted, however, that accurate

responding maximized earnings. All subjects in the contingent pretraining group earned more money (75% more on the average) for their performance than they would have for their hourly wage.

Second, the 5 X 5 display grid in this study was a matrix of rectangles on a computer monitor instead of the matrix of lights used by Schwartz. Given subjects' possible history with "computer games" this could have induced more variability in performance. To the extent that these minor variations were responsible for the failure to replicate, the practical significance of Schwartz's findings is undermined. Our experimental preparation is clearly much more similar to that of Schwartz than is an applied setting, or even other experimental settings. Reinforced pretraining of a particular sort may interfere with later problem-solving for some narrowly defined tasks in carefully controlled settings, but the present data seemingly indicate these effects will not be generally found with a wide variety of tasks and settings.

Another issue is the reliability of measurement. Deciding whether or not a subject's guess was correct required careful, but quick, thought. For some problems a correct solution could be stated in a variety of ways. The interaction between the experimenter and the subject also provides an opportunity for more subtle factors to influence the behavior of the subjects. One example of this could be the tone of voice used by the experimenter when he tells the subject that a guess is incorrect.

We attempted to produce reliable judgments about problem solutions by using written criteria for accuracy and having an independent judge rate the correctness of a sample of the subjects' hypotheses. Reliability of experimenter judgments was not reported by Schwartz. It also seems rel-

atively unlikely that experimenter bias was present in this experiment since the failure to replicate was unexpected.

Even if Schwartz's findings were robust and easily replicated, the implications for applied settings would remain unclear. One would normally use pretraining to establish an adequate base level of performance. Schwartz's procedure required subjects to complete many more trials after mastering the task. (Six of our subjects were required to complete 850 more trials after obtaining 98-100% accuracy in a 50-trial block.) Schwartz's procedure may be more accurately described as "overtraining." In an applied educational setting such a procedure would clearly be seen as wasting students' time and an inefficient use of monetary reinforcers. Stereotyped responding may be an efficient strategy for coping with simple, repetitive tasks without any clear implications for future performance on more complex tasks.

The effects of reinforced pretraining on later problem-solving remain unclear. Our findings suggest that the effects observed by Schwartz are apparently difficult to obtain. In that context, Schwartz's findings do not give us any proximal reason to abandon or limit the use of reinforcement procedures that have been demonstrated to be effective in applied settings.

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