*COMPARING THE EFFECTS OF TWO CORRECTION
PROCEDURES ON HUMAN ACQUISITION OF
SEQUENTIAL BEHAVIOR PATTERNS*

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Thirty-one college undergraduates learned to touch abstract stimuli on a computer screen in arbitrarily designated "correct" sequential orders. Four sets of seven stimuli were used; the stimuli were arrayed horizontally on the screen in random sequences. A correct response (i.e., touching first the stimulus designated as first) resulted in that stimulus appearing near the top of the screen in its correct sequential position (left to right), and remaining there until the end of the trial. Incorrect responses (i.e., touching a stimulus out of sequence) terminated the trial. New trials displayed either the same sequence as the one on which an error had occurred (same-order correction procedure), or a new random sequence (new-order correction procedure). Whenever all responses occurred in the correct sequence, the next trial displayed a new random sequence. Each phase ended when five consecutive correct response sequences occurred. Initially, the same-order correction procedure increased control by the position as well as by the shape of the stimuli; also, it produced more errors, more total trials, more trials to mastery, and more individual patterns of reacquisition than were produced by the new-order procedure.

Key words: correction procedures, sequential ordering, sequential behavior patterns, human adults

Responding to a set of simultaneously available stimuli in particular sequential orders is an important form of complex human behavior. Such patterns, which we call sequential ordering, are evident in tasks such as serial learning, chaining, and verbal learning. When studied with pigeons, acquisition of sequential ordering has been called serial learning (Straub, Seidenberg, Bever, & Terrace, 1979; Straub & Terrace, 1981); however, this is probably a misnomer, for the procedures for studying sequential ordering and serial learning differ in some important respects. Sequential ordering presents a unique, if limited, case in that sequenced responding occurs in the presence of the stimuli to be sequenced, but not in their absence. The sequenced responding of serial learning, as well as that of chaining and language, occurs at least sometimes without a display of simultaneously available stimuli. Sequential ordering, however, more closely parallels the language-like behavior of chimpanzees in paradigms such as those used

by Rumbaugh (1977). In these paradigms, all stimuli are constantly available, a response must be to one of those stimuli at a time, and the sequential pattern of responses is the subject of interest.

Understanding sequential ordering presents complex problems because there are several variables that interact in its acquisition and maintenance. These include: (1) instructions (with human subjects), (2) characteristics of the stimuli to be ordered, (3) the manner of presentation of those stimuli within trials, (4) feedback, or lack of it, following correct and incorrect responses, and (5) reinforcement (where separable from feedback). The effects of some of these variables on sequential ordering have been examined with nonhuman subjects, but little or no comparable research has been done with human subjects.

Several studies have been conducted on pigeons' sequential ordering (Richardson & Bittner, 1982; Richardson & Warzak, 1981; Straub et al., 1979; Straub & Terrace, 1981). In each of these studies, pigeons pecked at four differently colored keys, and reinforcement occurred when the four responses had occurred in a particular, arbitrarily determined order. An error—pecking at a color out

An earlier version of this paper was presented at the annual meeting of the Association for Behavior Analysis, Nashville, Tennessee, May 1984. Reprints may be obtained from S. M. Deitz, Educational Foundations Department, Georgia State University, University Plaza, Atlanta, Georgia 30303.

of its experimenter-determined sequence—resulted in a brief timeout followed by presentation of a new trial. However, the studies differed in several ways. First, the initial training procedures, as well as the final contingencies, were quite different. Richardson and Warzak and Straub *et al.* first used a backward-chaining procedure and then changed to a forward-chaining procedure during acquisition training. Straub and Terrace began training with autoshaping and moved first to a period of successive training and then to a period of simultaneous training. Richardson and Bittner used pigeons with histories of reinforced sequential ordering, so no initial training was required.

Second, initial and final feedback conditions differed. In the Richardson studies, the key brightened after a correct selection (on-key feedback), and a copy of the correct color appeared in the correct sequence on a higher panel (off-key feedback). Incorrect responses ended the trial. In the study by Straub *et al.* (1979), the on-key feedback was used but not the off-key feedback. In the Straub and Terrace (1981) experiments, the only feedback provided was a click after both correct and incorrect responses. Third, there were differences in the kind of response on which reinforcement was contingent. Whereas the Richardson studies counted a repeat peck as an error, thus terminating a trial, the Straub studies did not count repeat pecks as errors.

Finally, the studies differed in terms of what was called a “correction procedure.” In the Richardson studies, errors resulted in a new trial displaying the stimuli in the same order as on the previous trial. A new sequential order appeared only after a correct trial. The Straub *et al.* (1979) experiment also began with the correction procedure but changed to a procedure in which every trial displayed the stimuli in a new order because “the correction procedure showed no evidence of improving accuracy of performance” (p. 139). Straub and Terrace (1981) used only the new-order procedure.

These methodological differences make it difficult to judge the effects of history on acquisition, and the effects of the final contingencies on maintenance of sequential ordering. They indicate, however, an area where additional research is warranted. In the present study, the effects of two different correc-

tion procedures on the acquisition and maintenance of sequential ordering by human subjects were investigated. Instructions, stimuli, feedback, and reinforcement were held constant, and the differential effects of presenting the stimuli in the same order, or in a new order after each error, were examined.

METHOD

Subjects

Thirty-six students, 15 male and 21 female, enrolled in two undergraduate classes of educational psychology, served as subjects in this study. Their ages ranged from 19 to 32 years (mode = 23). All subjects in both classes were required to sign up for the study, to arrive at their designated time, and to read the instructions explaining the study. They were told that if after reading the instructions they chose not to participate, all requirements were still satisfactorily met. Two subjects chose not to participate and three others quit during the experiment, one from Group 1 and two from Group 3. Therefore, data were available only on the remaining 31 subjects (13 male, 18 female).

General Procedure

Subjects were seated in a chair in front of a desk on which a TRS® 80 Model III microcomputer was placed. The computer was equipped with a light pen. All instructions, stimuli, and feedback were presented by the computer.

Instructions. When subjects arrived, they were taken into the room, asked to sit, and handed the light pen. They were told the only instructions they would receive were those on the computer screen, and that no questions could be answered by the experimenter. The experimenter then left the room.

All subjects received the following minimal instructions:

A row of graphic characters like this is about to appear on the screen. They are in the wrong order. Your task is to figure out the correct order. You make your selections by touching the light pen you have in your hand to the flashing block under the characters. Touch one block at a time, until you have put all symbols in the correct order. When the computer is sure you have learned

Fig. 1. The symbols used in each phase of the experiment are shown in the sequential orders that were designated as "correct."

the order, new symbols with a new order will appear for you to learn. You may stop any time you wish, and the computer will tell you when the experiment is over. If you agree to participate touch the light pen to the dot next to "YES." If you don't want to participate touch the light pen to the dot next to "NO."

Information was provided about the task but not about the contingencies or feedback conditions.

If the subject touched "NO," the instructions were removed, and the computer printed, "Thank you, you may leave." on the screen. If "YES" was touched, the instructions were removed and the screen printed, "Touch this block when you are ready to begin the experiment." This response served only as a signal to the computer to begin timing and recording responses.

Stimuli. Each subject learned a sequential order of seven stimuli in each of four sets. Each sequence that was designated as "correct" was simply one of many random orders generated by the computer; there were no predetermined patterns or systems as to which sequence was designated as the correct one. The 28 stimuli were Radio Shack video graphic characters that could be displayed on the screen. Figure 1 shows the correct sequence for each set of stimuli. Each set was one problem and each problem was presented as a separate phase of the experiment. No matter which experimental condition was in

effect, all subjects experienced Problem 1 first, Problem 2 second, and so on.

The seven stimuli were presented horizontally across the screen. Under each stimulus was a flashing block. Above the row of stimuli was a midline dividing the screen horizontally. A trial consisted of all responses to one such presentation of the stimuli. Within each trial, the task was to touch the blocks under the stimuli in the sequence indicated left to right in Figure 1. The stimuli were never presented in that correct order.

Feedback. Several types of feedback were arranged. "Response Feedback" (RF) indicates that the computer registered a response. When a subject touched a block under a stimulus with the light pen, the block changed to an "x" for 1 s and changed back to a flashing block. If the response was correct (i.e., responding at a stimulus in the sequential position designated as correct for that stimulus), it was followed by RF and "Order Feedback" (OF). With OF, as soon as the correct response was made, an exact copy of the stimulus appeared in its correct ordinal position above the midline on the screen. All seven stimuli below the midline, as well as the copies above the midline produced by correct responses, remained throughout the trial. Thus, when all seven stimuli were responded at in the correct order, a picture of the correct order was generated above the midline (Figure 1). At that point, the screen remained on for 2 s; it then went blank for 2 s and a new trial began. Copies produced above the midline on previous trials did not reappear on the next trial unless produced by correct responses in the new trial.

If the response was incorrect (i.e., responding to a stimulus out of sequential order), it was followed by RF and "Feedback for Incorrect Responding" (FIR). With FIR, the trial was immediately terminated. The screen went blank for 2 s after which the next trial began.

Subjects completed a problem/phase by responding to all seven stimuli in the correct order in five consecutive trials. This was the steady-state criterion. All 31 subjects completed all four problems.

Design

Subjects were randomly assigned to four groups. Groups 1 through 4 (G-1-G-4) were

Table 1

Sequence of experimental conditions for each group in successive phases; S-O = same order and N-O = new order.

Group	Phase 1	Phase 2	Phase 3	Phase 4
1	S-O	S-O	S-O	S-O
2	S-O	N-O	S-O	N-O
3	N-O	S-O	N-O	S-O
4	N-O	N-O	N-O	N-O

assigned eight (3M, 5F), nine (3M, 6F), eight (5M, 3F), and six (2M, 4F) subjects, respectively. Regardless of which correction procedure was in effect, all subjects received identical instructions and worked in continuous sessions. Each subject worked at Problem 1, then Problem 2, and so on, in that order, until the experiment was completed or until 90 min had elapsed. The feedback system discussed above was in effect for all subjects; a short break (≤ 5 min) was allowed between Problems 2 and 3.

Conditions differed according to the type of correction procedure in effect. In the Same-Order (S-O) correction procedure, the next trial after an incorrect response was a presentation of the stimuli in the same sequential order as in the previous trial where the error had been made. Subjects therefore saw the stimuli in the same order on each trial until they touched the squares below all seven stimuli in the correct sequence within one trial. Only after a completely correct trial was a new sequence of the stimuli presented.

In the New-Order (N-O) correction procedure, each trial consisted of a randomly selected new order of the seven stimuli, whether or not an error occurred on the previous trial. The two correction procedures were alike in that new sequential orders of the stimuli appeared after a correct trial. They were different in that the S-O procedure required working at one sequence until all stimuli were responded at correctly, whereas the N-O procedure frequently changed the displayed sequence of stimuli. The order in which each group was exposed to these experimental conditions is shown in Table 1.

Measurement

The number of responses per trial and their latencies were recorded by the computer. "Correct responses" consisted of all selections

Table 2

Data obtained under the S-O and N-O procedures in Phase 1; mean and (standard deviation) are given for each measure.

Dependent measures	S-O	N-O
	(G-1 & G-2)	(G-3 & G-4)
Trials to 1st correct seq.	28.6 (19.9)	44.4 (48.4)
Total trials	75.6 (32.6)	54.5 (48.3)
Trials to mastery	47.0 (28.9)	10.1 (7.5)
Total errors	53.5 (31.8)	35.6 (50.0)
Repeat incorrect resp.	5.7 (9.9)	5.6 (5.0)
Forward errors	43.8 (28.6)	28.2 (48.4)
Backward errors	4.0 (2.2)	1.8 (11.5)
% of errors	0.6 (0.2)	0.5 (0.3)
Correct resp.	178.1 (48.1)	102.1 (43.1)
% of correct resp.	2.6 (0.8)	2.5 (1.0)
Correct seq.	11.5 (2.9)	7.8 (4.5)
% of correct seq.	0.2 (0.1)	0.2 (0.1)
Reacquisition	2.1 (1.6)	0.1 (0.3)

of stimuli in the designated sequential order. "Incorrect responses" were those in which an incorrect stimulus was selected before any form of order feedback or feedback for incorrect responding was given for that stimulus or for that position. "Repeat incorrect responses" were selections of stimuli after feedback for incorrect responding and before order feedback occurred (e.g., selecting 3 a second time for position 1 before selecting 1 for position 1). "Errors" consisted of all incorrect responses after any form of order feedback or feedback for incorrect responding; therefore, they included repeat incorrect responses as well as forward and backward errors. A "forward error" occurred when a stimulus was selected ahead of the currently correct stimulus (e.g., selecting 1 then 2 then 4) and a "backward error" occurred when a stimulus was selected from an earlier portion of the correct order (e.g., selecting 1 then 2 then 1 again). The percentage of errors was calculated by dividing the total errors by the total trials.

A "correct order" was a trial in which all 7 stimuli were selected in the correct sequence. To obtain the percentage of correct orders, correct orders were divided by total trials. "Total trials" consisted of all the trials in a phase. "Trials to the first correct order" included all the trials before the first correct order. "Trials to mastery" consisted of the number of trials from the first correct order to the end of a phase. "Reacquisition" was a period of relearning the correct sequence after having emitted it once; it consisted of any two

successive correct trials separated by five or more incorrect trials.

RESULTS

The effects of three types of independent variables were analyzed: (1) the correction procedures, (2) experimentally imposed histories, and (3) practice.

Correction Procedure Effects

Correction-procedure effects uninfluenced by practice and the effects of imposed experimental history were examined in data from Phase 1 for all subjects exposed to the N-O and S-O conditions.

As shown in Table 2, subjects in the S-O procedure produced the first correct sequence after fewer trials than did the subjects in the N-O procedure. However, S-O subjects required more total trials to reach the steady-state criterion than did the N-O subjects. Once the first correct order was produced, the N-O subjects took fewer trials to mastery than did the S-O subjects. All subjects in the S-O procedure required more trials to mastery than the mean number of trials to mastery for subjects on the N-O procedure (see Table 2 and Figure 2).

Table 2 shows that subjects under the S-O procedure in Phase 1 produced five consecutive correct sequences with more total errors than were produced by subjects under the N-O procedure. However, this difference between the means for the two procedures in Phase 1 was considerably smaller when the percentages of errors (errors/total trials) were compared. Similarly the S-O subjects emitted more correct responses and more correct sequences before reaching the steady-state criterion. These differences also were reduced when the percentages rather than the totals were compared.

The criterion for reacquisition was at least five trials separating correct sequences. These are designated by arrows in Figures 2 and 3. Fourteen of the 17 S-O subjects had pronounced patterns of reacquisition, whereas only one of the 14 N-O subjects demonstrated reacquisition. Reacquisition occurred from zero to five times with an average of 2.1 for the S-O subjects and from zero to one time with an average of 0.1 for the N-O subjects (see Table 2 and Figures 2 and 3).

Experimental-History Effects

Experimental-history effects were studied by examining the data from Phase 2 relative to the data from the condition to which the same subjects were exposed in Phase 1. Those in group G-1 were exposed to S-O after an S-O history; those in G-2 were exposed to N-O after an S-O history; those in G-3 were exposed to S-O after an N-O history; and those in G-4 were exposed to N-O after an N-O history (Table 1).

Figure 4 shows the numbers of correct responses per trial for subjects in G-1 during Phases 1 and 2. When the S-O procedure was followed by the S-O procedure, all subjects except one (S-20) demonstrated mastery in fewer total trials during Phase 2 than during Phase 1. All subjects except two reached steady-state performance with fewer trials to mastery during Phase 2 than during Phase 1. One subject (S-7) produced an equal number of trials to mastery in both phases, while another subject (S-20) produced more trials to mastery in Phase 2 than in Phase 1. All subjects except two produced fewer reacquisitions during Phase 2 than during Phase 1. The remaining subjects (S-3 and S-20) each produced an equal number of reacquisitions during both phases.

Figure 5 shows the numbers of correct responses per trial for subjects in G-2 during Phases 1 (S-O) and 2 (N-O). Each subject produced fewer total trials and fewer trials to mastery during Phase 2 than during Phase 1. All subjects except two produced fewer reacquisitions in Phase 2 than in Phase 1; the remaining subjects (S-23B and S-28) produced no reacquisitions during either phase.

Figure 6 shows the numbers of correct responses per trial for subjects in G-3 during Phases 1 (N-O) and 2 (S-O). Six of the 8 subjects reached steady state with fewer total trials during Phase 2 than during Phase 1. Four subjects (S-11, S-16, S-9B, S-12) produced more trials to mastery during Phase 2 than during Phase 1, while 3 other subjects (S-25B, S-26, S-18) produced fewer trials to mastery during Phase 2 than during Phase 1. The remaining subject (S-19) produced an equal number of trials to mastery in both phases. One subject (S-26) produced fewer reacquisitions in Phase 2 than in Phase 1, while 3 other subjects (S-16, S-18, and S-19) produced no reacquisitions in either phase.

Fig. 2. The numbers of correct responses per trial on successive trials are shown for each subject exposed to the S-O correction procedure in Phase 1.

Fig. 3. The numbers of correct responses per trial on successive trials are shown for each subject exposed to the N-O correction procedure in Phase 1.

Fig. 4. The numbers of correct responses per trial are shown for each subject in Group G-1 during Phases 1 (S-O) and 2 (S-O).

Fig. 5. The numbers of correct responses per trial are shown for each subject in Group G-2 during Phases 1 (S-O) and 2 (N-O).

NEW-ORDER CORRECTION PROCEDURE AFTER SAME-ORDER CORRECTION PROCEDURE

SAME-ORDER CORRECTION PROCEDURE AFTER NEW-ORDER CORRECTION PROCEDURE

Fig. 6. The numbers of correct responses per trial are shown for each subject in Group G-3 during Phases 1 (N-O) and 2 (S-O).

Fig. 7. The numbers of correct responses per trial are shown for each subject in Group G-4 during Phases 1 (N-O) and 2 (N-O).

The 4 remaining subjects each produced more reacquisitions during Phase 2 than during Phase 1.

Figure 7 shows the correct responses per trial for subjects in G-4 during Phases 1 (N-O) and 2 (N-O). Two subjects (S-29 and S-35) produced more total trials during Phase 2 than during Phase 1, whereas the remaining 4 subjects produced fewer total trials in Phase 2 than in Phase 1. Four subjects (S-4, S-30, S-29, and S-35) produced more trials to mastery during Phase 2 than during Phase 1, whereas

the 2 remaining subjects produced fewer trials to mastery in Phase 2 than in Phase 1. One subject (S-4) produced one reacquisition in Phase 2 and no reacquisitions in Phase 1. No other subjects produced any reacquisitions in Phase 1 or in Phase 2.

Practice Effects

Performance in Phase 4 by all groups showed the effects of practice. As Table 3 shows, all differences among the groups es-

Table 3
Means and (standard deviations) obtained for each group in Phase 4 for all measures.

Dependent measures	S-S-S-S (G-1)	S-N-S-N (G-2)	N-S-N-S (G-3)	N-N-N-N (G-4)
Trials to 1st correct sequence	12.0 (2.9)	17.8 (4.8)	10.6 (3.2)	14.0 (5.6)
Total trials	25.0 (9.2)	26.7 (8.7)	23.9 (8.8)	25.8 (13.3)
Trials to mastery	13.0 (6.4)	8.9 (6.0)	13.3 (8.0)	11.8 (12.0)
Total errors	6.3 (5.1)	8.2 (8.1)	6.5 (5.1)	8.0 (10.9)
Repeat incorrect responses	1.0 (1.6)	3.0 (1.7)	0.8 (0.9)	1.8 (1.6)
Forward errors	4.9 (5.1)	4.3 (6.1)	5.7 (5.5)	6.0 (10.5)
Backward errors	0.4 (0.5)	0.9 (1.7)	0.0 (0.0)	0.2 (0.4)
% of errors	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.2 (0.2)
Correct responses	94.8 (33.5)	82.8 (28.2)	88.8 (34.2)	90.8 (47.1)
% of correct responses	3.8 (0.5)	3.1 (0.5)	3.7 (0.4)	3.6 (0.7)
Correct sequences	8.8 (2.9)	6.7 (1.7)	7.9 (2.5)	7.8 (3.8)
% of correct sequences	0.4 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)
Reacquisition	0.3 (0.5)	0.1 (0.3)	0.5 (0.5)	0.2 (0.4)

entially disappeared with practice. The only difference was that reacquisition patterns were still being produced more by the S-O procedure (6 of 16 subjects) than by the N-O procedure (2 of 15 subjects; see Figure 8). By Phase 4 all subjects efficiently learned this task and individual variability was greatly reduced.

Latency Data

Latencies were highest during early trials. Often 1 to 4 min elapsed before the first or second selection. Higher latencies tended to occur on errors (the last response in a trial) than on correct responses. The latencies of forward errors were greater than those of backward errors, and there were very few backward errors. Beyond those findings, latencies tended to be about the same throughout the experiment (1–3 s) and most of that time can be accounted for by the necessity of finding the stimulus in the order being presented.

DISCUSSION

The data and conclusions of this study emphasize acquisition rather than steady-state performance. Although in the experimental analysis of behavior the study of steady-state performance is more usual (see Sidman, 1960), here the analysis of acquisition was necessary

because with human subjects the effects were observed only during acquisition. Identifying factors responsible for efficient and inefficient acquisition may help in teaching new behavior and placing existing behavior under stimulus control.

In Phase 1, the S-O correction procedure produced different patterns of response than did the N-O correction procedure. Initially, correct sequences occurred more rapidly, but more trials were required before initial mastery occurred and more total trials were necessary to meet the steady-state criterion. Total numbers of errors, correct responses, and correct sequences were also greater under the S-O procedure than under the N-O procedure. However, the percentages of total errors, correct responses, and correct sequences, calculated by dividing each by the total number of trials, were similar for the S-O and N-O procedures. This is not surprising inasmuch as trials are artifacts of errors, and numbers of correct responses and correct sequences are artifacts of the trials.

The N-O correction procedure facilitated sequential ordering more effectively than did the S-O correction procedure. Although under the S-O procedure, the first correct sequence occurred in fewer trials than under the N-O condition, the S-O condition resulted in more trials before mastery and increased frequency of reacquisition patterns. The increased oc-

Fig. 8. The numbers of correct responses per trial during Phase 4 are shown for each subject in Groups G-1 (S-O), G-2 (N-O), G-3 (S-O), and G-4 (N-O).

currence of reacquisition patterns produced by the S-O correction procedure suggests that S-O may have initially established control by other aspects of the stimuli such as their position within a trial. Because trials with errors were followed by trials with the stimuli reappearing in the same order, only S-O subjects could respond correctly by attending to the positions of the stimuli and ignoring their shapes.

The reacquisition data support the possibility of such extraneous control. After a correct response sequence, the same stimuli were presented in a different order and it became necessary to learn the correct sequence again. The remaining contingencies within the task (e.g., feedback for correct responses, new orders after correct trials, etc.) eventually transferred control from position to shape, but such transfer was an unnecessary and possibly detrimental effect of the S-O correction procedure. Once these other contingencies gained control, they apparently maintained control. Still, the S-O correction procedure does not appear to be an efficient way to present a sequential ordering task. S-O presents this task so that it "provides the learner with the option of attending to features of the presentation that are irrelevant to the desired generalization" (Engelmann & Carnine, 1982, p. 261).

In this study, then, major differences were found on such a seemingly insignificant factor as the order of stimulus presentation following an error. Other independent variables might be more important in terms of influencing the acquisition of sequential ordering, as evidenced by the fairly significant intersubject variability. Variables such as instructions, type of stimuli, feedback, and reinforcement interact in the acquisition of sequential ordering.

We used no specific reinforcement beyond the feedback variables. This was done to mimic conventional applications of computer-assisted instruction and to avoid confusing the functions of similar variables. Order feedback was used to signal correct responses because Richardson and Bittner (1982) had found its absence to be detrimental to correct responding. The stimuli were abstract to lessen any previously acquired control that might produce effects unknown to the experimenters.

Finally, we were able to compare these two correction procedures by limiting the impact of instructions. Vague instructions referring to the behavior but not to the contingencies were

necessary so that an identical set of instructions could be used with all subjects, no matter what procedure was in effect. This allowed the contingencies to produce the different patterns of responding with little influence of the instructions, an effect which is often difficult to obtain with human subjects (see Baron & Galizio, 1983; Byron, Catania, & Shimoff, 1985; Lowe, 1979; Weiner, 1983).

These factors all require future research. Currently we know something about the contribution of correction procedures to variability in the acquisition of sequential ordering. The S-O correction procedure turned out to be no correction procedure at all; it impeded rather than facilitated the specified behavior. Although practice eventually obviated the detrimental effects of the procedure, it would be difficult to justify its use in future research on acquisition of sequential ordering.

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Received November 1, 1984

Final acceptance February 21, 1986