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FEEDBACK EFFECTS ON SEQUENTIAL ORDERING IN HUMANS

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Under various feedback conditions, 38 college undergraduates were asked to rearrange abstract graphic characters on a computer screen, placing them in arbitrarily designated "correct" sequences. Two sets of seven horizontally arrayed stimuli were used. In Experiment 1, subjects in Group 1 learned to arrange the first set under Selection Feedback in which a "+" appeared above each character after it was selected in the correct order and to arrange the second set under Order Feedback in which a correct response produced a copy of the character in its correct ordinal position at the top of the screen. For Group 2 the order of these conditions was reversed. In Experiment 2, for subjects in Group 3, correct responses produced neither of these types of feedback. Subjects in Group 4 received Order Feedback only until the first set was correctly ordered once. Order Feedback was more effective than Selection Feedback during initial acquisition of the first set but not during maintenance; no differences were found for the second set. Only 2 of 9 subjects successfully put the characters in correct sequential order under the No Feedback condition. When, in Experiment 2, Order Feedback was eliminated after the first correctly arranged sequence, the steady-state criteria were met more slowly than in Experiment 1.

Key words: feedback, sequential ordering, sequential behavior patterns, human adults

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The effects of "feedback" have been a recurrent topic in psychology. Feedback is sometimes argued to be different than reinforcement, with its effectiveness said to be dependent, at least in part, on the amount of "information" it contains (Comstock & Chumbley, 1973; Thorndike, 1927; Trowbridge & Cason, 1932). Such information is commonly, if somewhat loosely, defined with respect to judging responses as correct or incorrect. As Parsons (1982) stated, however, "It is not clear how, if at all, the amount of information in information-feedback determines control over later responding" (p. 14). He explained that reinforcement may differ from feedback, but noted that there has been little research attempting to examine this issue (see also Peterson, 1982).

Various forms of feedback have been shown to affect sequential characteristics of operant behavior (e.g., Boren & Devine, 1968; Richardson & Warzak, 1981; Vaughan, 1985). Hence, the effects of different types of feedback might be assessed with respect to that dimension of behavior. Sequential ordering consists of learning to respond to a set of continuously available stimuli in what the experimenter has determined is a "correct" sequence. Investigations of sequential ordering have used a variety of feedback conditions to establish and maintain correct sequences of four keylight colors with pigeons and of seven abstract computer graphic characters with humans. These feedback conditions differed in the several studies; one dimension along which they differed was the amount of information presented by the feedback.

In experiments by Straub, Seidenberg, Bever, and Terrace (1979) and Straub and Terrace (1981) pigeons' correct responses produced "on-key" feedback (the key brightened when a peck occurred in the correct sequence) during acquisition training; no such feedback was scheduled during steady-state performance. Richardson and Bittner (1982), Richardson and Kresch (1983), and Richardson and Warzak (1981) used on-key feedback as well as "off-key" feedback in establishing and maintaining pigeons' sequential ordering. Off-key feedback consisted of a second row of windows through which the stimuli were displayed in their correct sequence, one at a time, after each correct response. With this form of

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off-key feedback, a complete display of the correct sequence was available to the subject when a correct sequence was completed. Deitz, Fredrick, Quinn, and Brasher (1986) also used a form of off-key feedback to establish and maintain sequential ordering with human subjects. Structurally, at least, this off-key feedback differed from on-key feedback in that it seemed to add additional information to the situation.

Straub and Terrace (1981) stated that the absence of feedback for correct responding during steady-state performance demonstrated that feedback was unnecessary for a "high level of accuracy" (p. 455). In contrast, Richardson and Warzak (1981) found that their pigeons emitted higher average percentages of correct sequences with feedback than those reported in the Straub and Terrace study without feedback (70% versus 57%). Furthermore, even though feedback was used during acquisition, Straub et al. (1979) claimed that their data from steady-state performance without feedback showed that "pigeons can learn a sequence of four stimuli without successive feedback following each response" (p. 138). Straub and Terrace (1981) concluded that "in the absence of control by successively presented exteroceptive stimuli," it is necessary to consider that pigeons used "internal representations" (p. 455) of the sequence to perform the task.

These comments raise several questions. First, it is unclear whether the different types of feedback (on-key, off-key) have different effects on acquisition and on maintenance of sequential ordering. It is possible that differences between steady-state performances in the various studies were related to the feedback received during acquisition. Because the two types of feedback could be said to contain different amounts of information, this suggests that there are different effects on responding. Richardson and Bittner (1982) compared the effects of on-key and off-key feedback on error patterns in the steady-state sequential-ordering performance. They found that the addition of off-key feedback was less important than on-key feedback and that the two types of feedback produced different error patterns. Their results were related only to steady-state performance, however. Extending this research to effects of different forms of feedback during acquisition training would further clarify these effects.

Second, because feedback was, in fact, used during acquisition in all of the studies mentioned above, it is difficult to support the claim by Straub et al. (1979) that pigeons "can learn a sequence" (p. 138) without some form of feedback. It is possible, however, that sequential ordering can be both acquired and maintained without feedback. The effects of the absence of feedback during the acquisition as well as the maintenance of sequential ordering need to be examined. Deitz et al. (1986), in examining how differences in the "correction procedures" used in the studies with pigeons accounted for some of the differences in the results, found that adult human subjects can acquire a more complex form of sequential ordering to a 100% correct steady-state criterion. Questions about the effects of the presence of feedback and of the several types of feedback may, therefore, be most clearly answered with adult human subjects. Also, if steady-state performance without feedback suggested that pigeons used "internal representations" to perform the task, that finding should be replicable with adult human subjects.

Two studies were conducted to investigate these issues. The first study was planned to assess whether different types of feedback for correct responding had different effects on the acquisition of sequential ordering. Forms of on-key and (the more "informative") off-key feedback for correct responses were compared while requiring repeated acquisition of correct sequences (Boren & Devine, 1968; Vaughan, 1985). In the second study, two ways to eliminate feedback for correct responding were examined. Some subjects were never exposed to feedback for correct responding during acquisition or steady state; others were exposed to feedback for correct responding during acquisition training after which the feedback was eliminated. In both experiments, minimal instructions were used and the general procedures were those previously found to be most effective for establishing sequential ordering (see Deitz et al., 1986) with human subjects.

METHOD

Subjects

Thirty-eight students, 11 male and 27 female, enrolled in an undergraduate educational psychology class, served as subjects.

Their ages ranged from 19 to 27 years (mode = 25). The instructor of the class cooperated with the experimenter in placing an experimental participation requirement in the course syllabus. All subjects were required to sign up for this experiment, to arrive at their designated time, and to read the instructions explaining the study. After reading the instructions, if a subject chose not to participate, he or she was allowed to leave with no penalty; all subjects agreed to participate.

Subjects were randomly assigned to four groups. The experiment was completed by 8 of 9 subjects in Group 1 (G-1), 8 of 9 subjects in Group 2 (G-2), 2 of 9 subjects in Group 3 (G-3), and 7 of 11 subjects in Group 4 (G-4). Of the 25 subjects who completed the experiment, 9 were male and 16 were female.

General Procedure

Subjects participated individually; each was asked to leave all objects such as books, paper, pencils, and purses outside the experimental room and was seated in a chair in front of a desk. A TRS 80® Model III microcomputer was on the desk; it was equipped with a light pen, which was handed to the subject. After explaining that all instructions and experimental conditions would be presented on the computer screen and that no questions could be answered, the experimenter left the room.

Instructions. The following instructions were presented on the computer screen to each subject:

> 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 touched all symbols in the correct order. When the computer is sure you have learned the order, new symbols with a new order may 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."

If a subject touched "NO," the computer printed, "Thank you, you may leave." on the screen. Touching the block next to "YES" resulted in the statement, "Touch this block when you are ready to begin the experiment." This response resulted in the computer beginning to record responses.

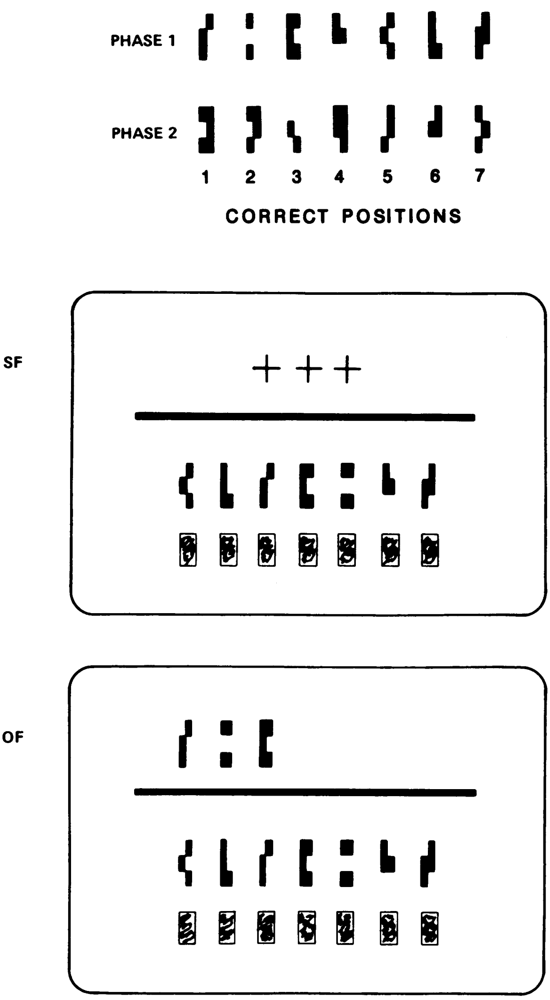


Fig. 1. The top portion shows the symbols used in Phases 1 and 2 in the sequential orders that were designated as "correct." The middle portion shows an example of the computer screen during the Selection Feedback (SF) condition at the point where three consecutive correct responses have been made. The bottom portion shows the screen during the Order Feedback (OF) condition at the point where three consecutive correct responses have been made.

Task and stimuli. Subjects in Groups 1 and 2 learned a sequential order of seven stimuli in each of two sets. Subjects in Groups 3 and 4 learned the sequence of the stimuli in the first set. The "correct" sequence of those stimuli, shown in the top of Figure 1, was simply one of many random sequences generated by the computer; there was no predetermined pattern or system as to which sequence was designated as correct. The 14 stimuli were Radio Shack video graphic characters that could be displayed on the screen. The seven characters were presented horizontally across the screen, but never in the correct sequence. Under each was a flashing block, and a line above the characters divided the screen horizontally. A trial consisted of all responses to one such presentation. Within each trial, the subject was to touch the blocks under the stimuli in the sequence indicated left to right in Figure 1. The steady-state criterion was met when the subject touched all seven stimuli in the correct sequence on five consecutive trials.

Feedback. Several types of feedback were arranged depending on the conditions in effect. For all subjects in all conditions, responses were immediately followed by Response Feedback (RF). RF indicated that the computer registered the response; the block changed to an "X" for 1 s and changed back to a flashing block. For all subjects in all conditions, if a response was incorrect (i.e., touching a stimulus out of sequential order), the trial was immediately terminated. The screen went blank for 2 s after which a new trial with the same stimuli in a new random sequence began (New Order correction procedure; see Deitz et al., 1986). Three other forms of feedback were arranged for correct responses. No other consequence followed any subject's behavior (i.e., no points, money, or other reinforcers were earned by subjects in this experiment).

Selection Feedback (SF) paralleled on-key feedback. In SF, a correct response was immediately followed by the placement of a "+" above the midline over the stimulus which the subject had correctly touched. SF provided only information regarding which responses had been correct. All seven stimuli below the midline as well as the "+" above the midline, produced by correct responses, remained throughout the trial. The middle of Figure 1 illustrates SF at the point in a trial where three consecutive correct responses have been emitted. When all seven stimuli were touched in the correct sequence, all stimuli had a "+" above them. At this point, the screen remained on for 2 s, it went blank for 2 s, and a new trial with the same stimuli in a new random sequence began. At the start of any new trial, no "+" produced by earlier trials remained; they were, however, produced by correct responses in the new trial.

Order Feedback (OF) paralleled off-key feedback. With OF, a correct response was immediately followed by the presentation of an exact copy of the stimulus in its correct ordinal position above the midline on the screen. OF provided information that the response was correct and showed the position of that response in the correct sequence. All seven stimuli below the midline as well as the copies above the midline were present throughout the trial. The bottom of Figure 1 illustrates OF at the point in a trial where three consecutive correct responses have been emitted. Thus, when all seven stimuli were touched in the correct sequence, a picture of the correct sequence, left to right, was generated above the midline. At this point, the screen remained on for 2 s, it went blank for 2 s, and a new trial with the same stimuli in a new random sequence began. At the start of any new trial, no copies produced above the midline on previous trials were reproduced on the screen unless produced by correct responses in the new trial.

No Feedback (NF) was a condition in which no stimulus event was arranged to occur after a correct response; in other words, the display remained exactly as it was before the response. RF continued as did the termination of a trial after an incorrect response but neither SF, OF, nor any other event followed a correct response.

Measurement. For each trial, the response positions and their corresponding stimuli were recorded by the microcomputer. "Correct responses" were all responses to stimuli in the designated sequential order; the percentage of correct responses was calculated by dividing the number of correct responses by the total number of responses. "Incorrect responses" were those in which an incorrect stimulus was selected as an initial "guess" in a particular position. In other words, these were incorrect selections of a stimulus before any form of SF, OF, or feedback for incorrect response was given for that stimulus or that position. Incorrect responses, therefore, were not counted as errors. "Errors" were selections of stimuli out of their designated sequential order after some form of feedback for correct or incorrect responding had previously occurred; the percentage of errors was computed by dividing the number of errors by the total number of responses. "Forward errors" occurred when a stimulus was selected ahead of the currently correct stimulus (e.g., selecting the first, then the second, and then the sixth stimulus of the correct sequence) and "backward errors" occurred when a stimulus was selected from an earlier portion of the correct sequence (e.g., selecting the first, then the second, and then the first again).

A "correct sequence" was a trial in which all seven stimuli were selected in the correct order; the percentage of correct sequences was computed by dividing the number of correct sequences by the total number of trials. "Total trials" was the number of trials that occurred before the steady-state criterion was met. "Trials to the first correct sequence" included all the trials before the first correct sequence. "Trials to steady state" consisted of the number of trials from the first correct sequence until the steady-state criterion was met. "Reacquisition" was a period of relearning the correct sequence after having once emitted it; reacquisition was defined as any two successive correct trials separated by five or more incorrect trials.

EXPERIMENT 1

Experiment 1 was conducted to determine whether structurally more informative feedback produced different effects on the acquisition of sequential ordering than was produced by structurally less informative feedback (Comstock & Chumbley, 1973). To address this issue, effects of the OF and SF procedures were compared. The data from Deitz et al. (1986) indicated that more than one repeated acquisition of sequential ordering was not informative about history effects; therefore only two phases were used in this study. Subjects in Group 1 learned the first sequence in Phase 1 with the SF procedure in effect and the second sequence in Phase 2 with the OF procedure in effect. Subjects in Group 2 learned the first sequence in Phase 1 with the OF procedure in effect and the second sequence in Phase 2 with the SF procedure in effect.

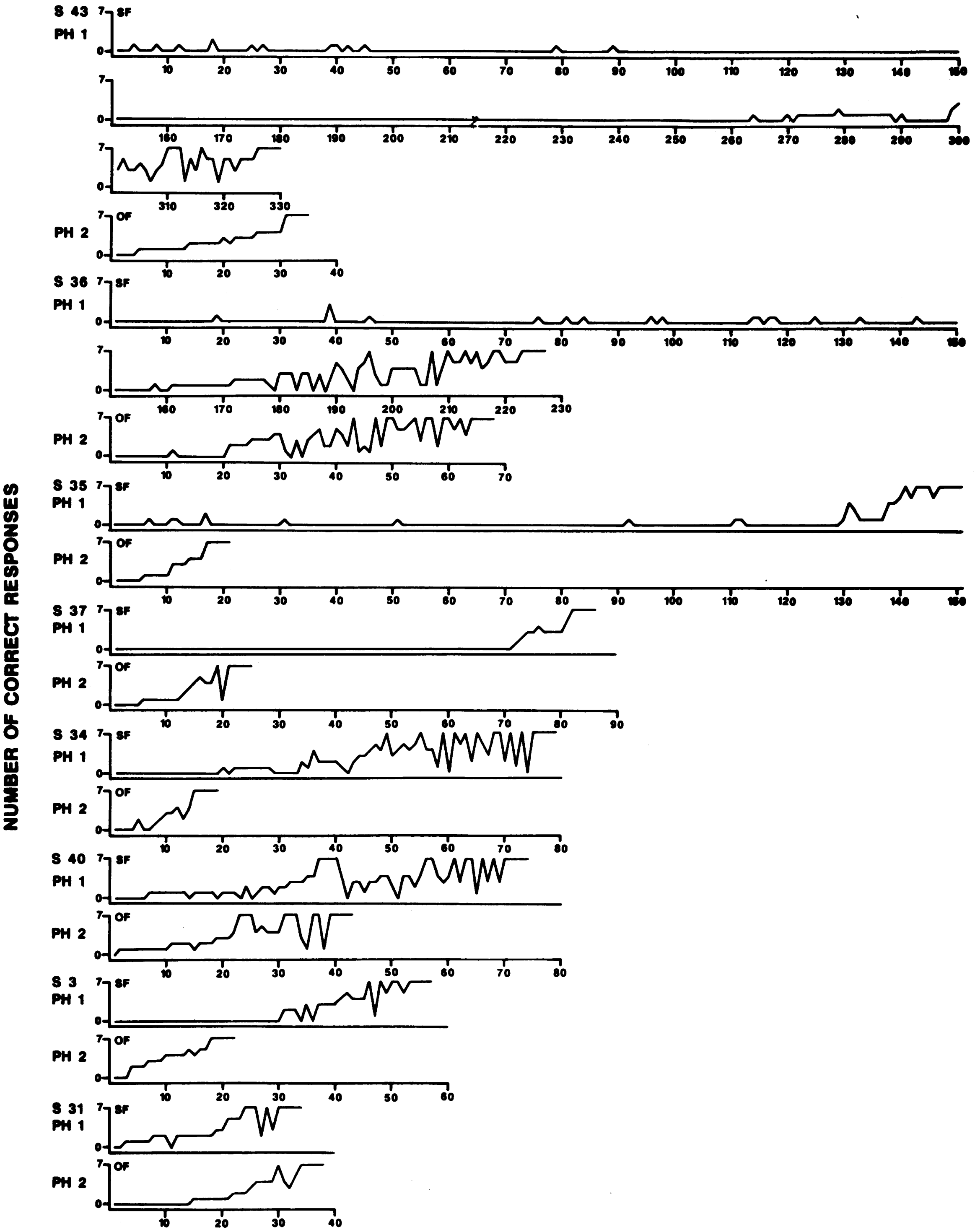
RESULTS

The data from Phase 1 most clearly illustrate the different effects of the SF and OF procedures. Table 1 and Figures 2 and 3 show that subjects under SF required more total trials to reach the steady-state criterion than did the subjects under OF. The Phase 1 sections of Figures 2 and 3 show that in the SF condition, only Subjects 3 and 31 emitted fewer total trials than any of the subjects in the OF condition. Most of the difference is accounted for by the number of trials to the first correct sequence. SF subjects required over three times as many trials to produce the first correct sequence as the OF subjects required; this was most noticeable in Subjects 43, 36, 35, and 37. Only 1 of the 8 subjects in the SF condition (S-31) emitted fewer total trials or trials to the first correct sequence than the mean numbers for those figures in the OF group. Once subjects had acquired the first correct sequence, there was very little difference in the number of trials required from the first correct sequence to steady state.

The SF procedure produced approximately the same number of incorrect responses as the OF procedure, but produced four times more errors. Even when controlled for the number of responses, the percentage of errors was twice as high under SF as under OF. Every subject in the SF group emitted more errors than the mean number of errors of the subjects in the OF group. The SF procedure produced slightly fewer backward errors but four times more forward errors. The number of correct responses required to finish the phase was somewhat lower under OF than under SF but the percentage of correct responses was considerably higher under OF than under SF. There were almost no differences between the conditions in the number of correct sequences, but the percentage of correct sequences was higher under the OF procedure. Reacquisitions produced by SF and OF were essentially identical and very low.

Phase 2 shows the effects of a history of sequential ordering under one feedback condition on acquisition of a new sequential order under the other feedback condition. The performance of all but 2 subjects (S-31 and S-5) improved from Phase 1 to Phase 2. With a history of training with either OF or SF, only very small differences occurred between the subsequent effects of the two procedures. Still, after a history of OF, subjects under the SF procedure required slightly fewer total trials than subjects under the OF procedure (29.8 vs. 33.9); there was a similar result for trials

PHASE 1 - SELECTION FEEDBACK (SF) PHASE 2 - ORDER FEEDBACK (OF)



TRIALS

Table 1

Means and (standard deviations) for each group in Phase 1 for all measures.

Dependent measures	G-1: SF (8 subjects)	G-2: OF (8 subjects)	G-3: NF (2 subjects)	G-4: OF–NF (7 subjects)
Total trials	129.8 (101.5)	49.8 (11.9)	54.5 (30.4)	93.9 (50.9
Trials to first correct	109.6 (99.8)	30.6 (12.7)	47.0 (33.0)	32.3 (16.6)
Trials to steady state	20.2 (12.4)	19.2 (10.6)	7.5 (3.5)	61.6 (52.5)
Total Responses	274.5 (138.0)	169.5 (41.5)	137.0 (35.4)	237.4 (110.1)
Incorrect Responses	12.1 (2.5)	11.8 (3.7)	11.0 (5.7)	12.8 (2.7)
Errors	107.1 (104.0)	27.2 (12.6)	37.0 (26.9)	71.0 (48.5)
% Errors	35.6 (20.9)	15.8 (5.8)	25.3 (13.1)	26.3 (10.1)
Forward errors	105.8 (103.1)	25.1 (11.3)	33.5 (24.7)	60.1 (38.1)
Backward errors	1.3 (2.8)	2.1 (1.9)	3.5 (2.1)	10.9 (13.9)
Correct responses	155.3 (62.0)	130.5 (34.6)	89.0 (2.8)	153.6 (64.5)
% Correct responses	60.5 (18.2)	76.8 (6.0)	66.9 (15.2)	66.4 (5.4)
Correct sequences	10.5 (3.6)	10.8 (3.7)	6.5 (2.1)	10.0 (4.5)
% Correct sequences	9.8 (7.7)	22.8 (8.9)	15.5 (12.6)	11.7 (3.0)
Reacquisitions	0.5 (0.5)	0.5 (0.8)	0.0 (0.0)	1.6 (2.1)

to the first correct sequence (19.5 vs. 23.5). Errors (11.1 vs. 12.9) and correct responses (95.9 vs. 101.3), although not the percentage of errors (8.6 vs. 9.1), were somewhat lower in Phase 2 under the SF condition. The OF procedure produced fewer correct sequences than the SF procedure did (7.5 vs. 8.3); SF produced a higher percentage of correct sequences (27.8 vs. 22.1). In most cases, for all of the measures, the differences were rather small and probably unimportant; very few differences are noticeable in any of the individual data in the Phase 2 sections of Figures 2 and 3.

EXPERIMENT 2

Experiment 2 was conducted to address two questions. First, could subjects learn to order a sequence if no differential feedback was produced by correct responses? Subjects in Group 3 were given the task of learning the first correct sequence while never receiving feedback for correct responses (NF condition). Second, once a sequence has been learned, can subjects continue to respond correctly if feedback for individual correct responses is discontinued? This question related to Straub and Terrace's (1981) invoking "internal representations" of the sequence as involved in performance of the task. Subjects in Group 4 were exposed to the OF procedure until the first correct sequence; for the remainder of the experiment, their correct responses produced no differential feedback (OF–NF condition). Repeated acquisitions were not employed in this experiment, because the data from Experiment 1 supported those of Deitz et al. (1986) in showing that only the first acquisition of a sequential order clearly illustrates differential effects of the stimulus conditions under investigation.

Results

Table 1 and Figure 4 show the effects of the NF and OF–NF conditions. Of the subjects in Group 3, who never received feedback for correct responses, only 2 learned the sequence. The bottom portion of Figure 4 shows that in terms of trials to the first correct sequence, S-46 took 76 trials and performed like the subjects under SF; S-45 took only 23 trials and performed more like the OF subjects. The other measures of performance for these 2 successful subjects are most like subjects in Group 2 (OF). Seven of the 9 subjects initially exposed to this procedure did not complete the task, however. Unlike the 2 subjects in Groups 1 and 2 who quit the experiment, the 7 subjects worked at the task for an average of 205.6 trials (range, 16 to 405) before quitting the experiment.

Subjects exposed to the OF–NF sequence performed comparably to subjects in the OF group until they had emitted the first correct

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Fig. 2. The numbers of correct responses per trial on successive trials are shown for each subject exposed to the SF condition in Phase 1 and the OF condition in Phase 2.

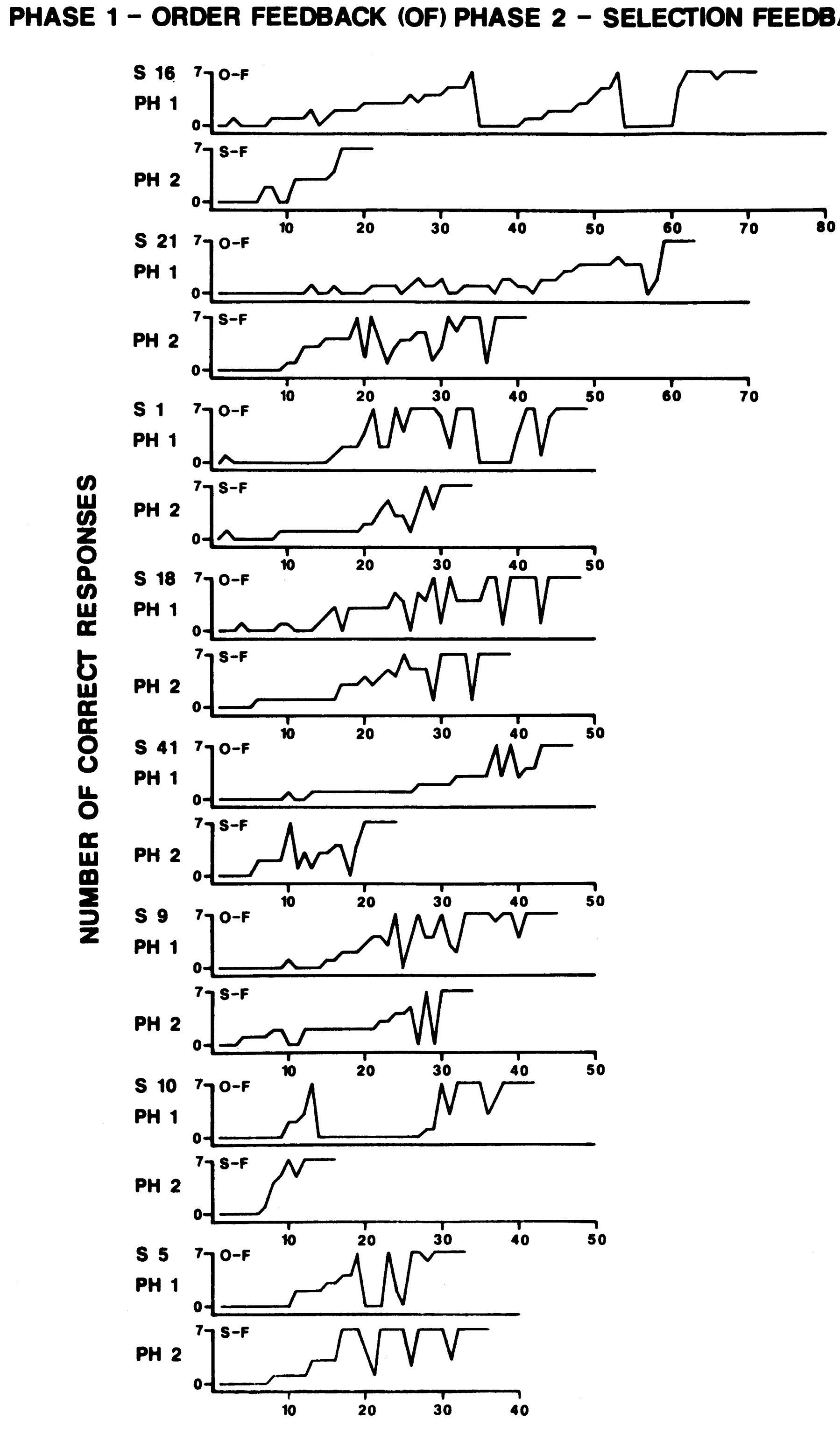

Fig. 3. The numbers of correct responses per trial on successive trials are shown for each subject exposed to the Order Feedback (OF) condition in Phase 1 and the Selection Feedback (SF) condition in Phase 2.

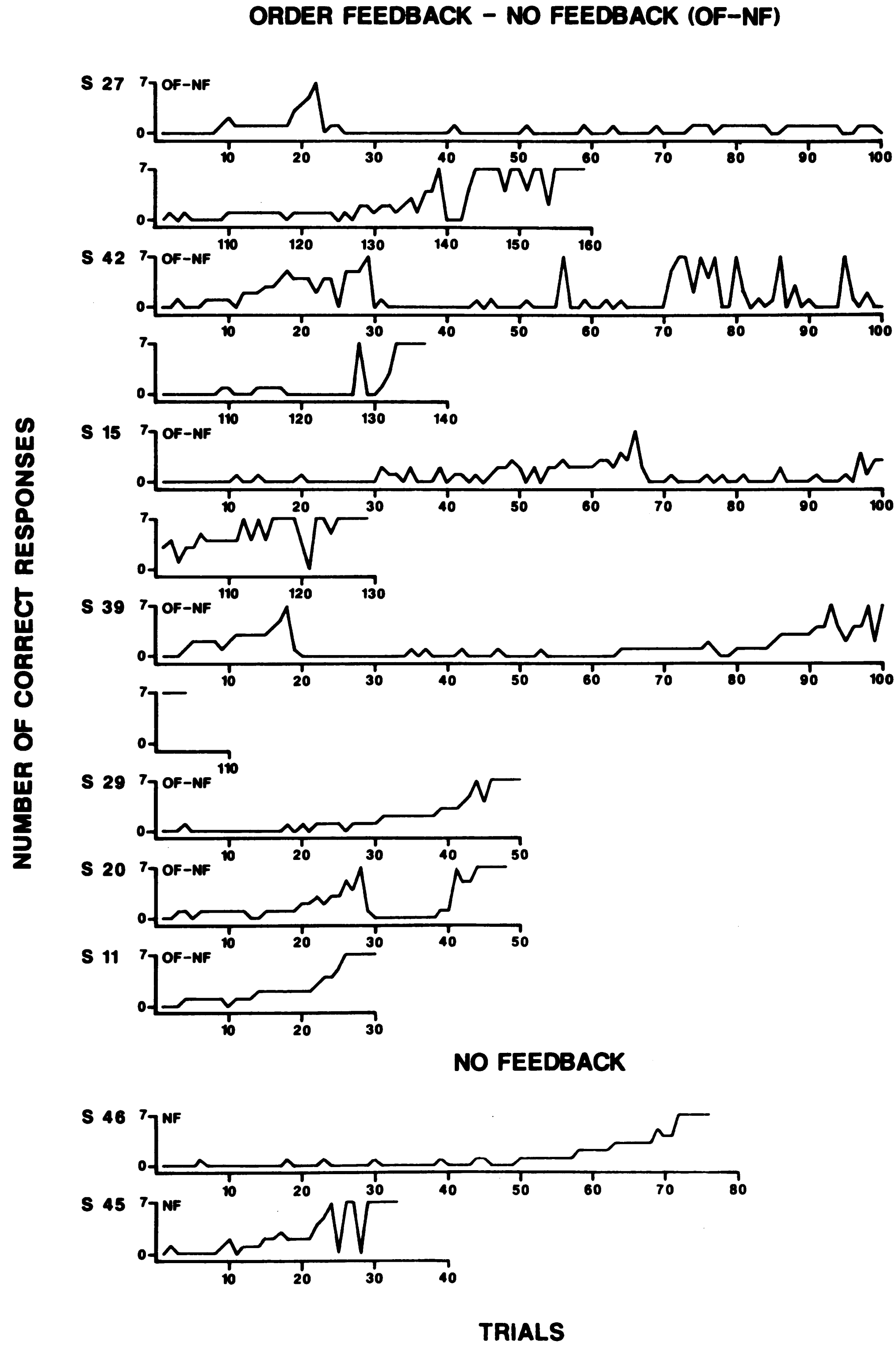

Fig. 4. The top portion shows the numbers of correct responses per trial on successive trials for each subject in the group exposed to Order Feedback followed by No Feedback (OF–NF). The bottom portion shows the numbers of correct responses per trial on successive trials for each of the 2 subjects who completed training under the No-Feedback (NF) condition.

sequence; the number of trials to the first correct sequence for these subjects was only slightly higher than that of the OF group. The top half of Figure 4 shows that for Subjects 27, 42, 39, 20, and 11, the first correct sequence occurred rapidly. Once the first correct sequence was emitted, the procedure was changed by eliminating feedback for correct responses, and the number of trials required from the first correct sequence until steady state was considerably higher than that of any other group. Eliminating feedback was not detrimental for Subjects 11, 29, and 20; they required only an additional 5, 7, and 21 trials to steady state, and the mean (11.0) for these 3 subjects was lower than that of the OF group. Subjects 15, 39, 42, and 27, however, required an additional 64, 87, 109, and 138 trials to reach steady state (M = 99.5). One of the 4 subjects who quit the experiment, and is therefore not represented in the data (S-24), emitted the first correct sequence then worked unsuccessfully for an additional 182 trials. As did subjects in Groups 1 and 2, the other 3 subjects quit quite early.

For subjects in the OF–NF condition, the mean data of total trials, total responses, errors, forward errors, and correct responses fell between those of the OF and the SF groups with most measures being closer to those of the SF group. The number of correct sequences was almost identical to that of the other groups. The number of reacquisitions, however, was three times higher in this group than in any other group; S-42 accounted for most of that difference, emitting six reacquisitions.

DISCUSSION

Feedback was shown to be an important contributing factor to the acquisition of sequential ordering. Order feedback produced faster, more efficient acquisition than did selection feedback. Subjects under the OF condition produced the first correct sequence in fewer trials, required fewer total trials to steady state, and emitted fewer errors than did subjects under the SF condition. However, trials to steady state (from first correct sequence to the meeting of steady-state criterion) were almost identical under either condition. Providing no feedback for correct responses produced difficulties. Seven of the 9 subjects exposed to the NF condition during acquisition did not learn the task. When order feedback was discontinued after the first correct sequence (OF–NF), most subjects were not capable of continuing to produce correct orders without considerably more practice. While trials to the first correct sequence under the OF–NF condition were comparable to those in the OF condition, the OF–NF condition produced three times as many trials from the first correct sequence to steady state.

The amount of information proved to be an important factor in the acquisition of sequential ordering. Selection feedback provided less information about correct responses than did order feedback, and was less effective for establishing sequential ordering. These data appear to contradict one finding of Richardson and Bittner (1982) and to support the position that the amount of information in feedback is the important factor. Richardson and Bittner found on-key feedback to be more important than off-key feedback, but their research was conducted during the steady-state performance of sequential ordering. While our data support the contention that order feedback (comparable to off-key) is more effective than selection feedback (on-key), that finding holds only for the acquisition stage of the behavior. During the period from the first correct trial to steady state (a period more comparable to the Richardson and Bittner data) and in the data from Phase 2, no important differences were observed between performances on the OF and SF conditions. These data suggest that the amount of information in feedback, if important at all, is relevant only to early stages of acquisition.

The structures of the two feedback procedures examined here provide some suggestions as to why order feedback was more effective during acquisition than was selection feedback. The latter facilitated discrimination of the alternative responses remaining to be selected—the symbols without a "+" over them. Subjects could select another stimulus without attending carefully to shape or required position of that stimulus. The OF condition, on the other hand required attending more closely to detail, or, in other words, to emit more behavior relevant to the stimuli. On this procedure, subjects could not identify remaining alternatives without comparing the stimuli on the feedback row with the stimuli on the response row. This suggestion is compatible with one made by Deitz et al. (1986) concerning the effects of various correction procedures. They found that one correction procedure seemed to induce control over responding by the position of the stimuli within a trial rather than by the shapes of the stimuli. Similarly, SF might have increased control by the appearance of the "+" above a stimulus rather than by the shapes of the stimuli. Such effects point to features of the stimulus arrangements other than the informative content of the stimuli.

The present results obtained with feedback for correct responses seem somewhat contrary to the findings of Straub et al. (1979) and support those of Richardson and Bittner (1982). The absence of feedback was found to create a number of difficulties. Even though Straub et al. used feedback during acquisition, they stated that "pigeons can learn a sequence of four stimuli without successive feedback following each response" (p. 138). Only 2 of the 9 human subjects, however, learned the sequence without feedback. In this condition, a correct response was signaled only by the absence of feedback for incorrect responses. In other words, after correct responses, nothing happened; no symbol appeared over the line and the screen did not go blank for the start of a new trial. Although the two successful performances show that this form of feedback can be effective, it appears that, at least with human subjects, a more obvious form of feedback is usually necessary, at least during the acquisition stage of sequential ordering.

When feedback was eliminated after occurrence of the first correct sequence, all 7 subjects remained in this condition, eventually reaching the steady-state criterion. It is difficult to assume that they did so, as Straub and Terrace (1981) claimed, by using "internal representations" (p. 455) of the order of those stimuli. Three of the subjects were able to continue emitting correct sequences once feedback was eliminated; the remaining 4 subjects experienced considerable difficulty before they began again to emit correct sequences. Eliminating feedback after acquisition, a process more similar to the one actually used by Straub et al. and Straub and Terrace, is more effective than acquisition with no feedback. In this case, the history of the organism during acquisition seems more informative than speculation about induced internal processes.

The necessary differences between human and animal experiments and experiences, however, may limit clear comparisons between these studies and those of Richardson and Bittner (1982) or of Straub and Terrace (1981). Although the sequences produced with pigeons and humans may be topographically similar, it is possible that such similarity resulted from different controlling variables. In terms of the acquisition of this type of task, for example, adult humans have a substantial history of left-to-right ordering, but pigeons do not. This history could make the off-key order feedback (OF) influential on humans; for pigeons, without such a history, off-key OF might have little effect.

Two other factors are relevant for experiments with only human subjects. First, as other researchers studying human operant behavior have shown, the effects of particular instructions are difficult to predict. The vague instructions used in these experiments described the behavior but not the contingencies, in an attempt to minimize the effects of those instructions (see Baron & Galizio, 1983; Buskist & Miller, 1986; Deitz et al., 1986; Matthews, Catania, & Shimoff, 1985). It is also possible, however, that these vague instructions were misleading to the subjects. Rather than allow the contingencies (in this case the types of feedback) to control behavior, some of the initial difficulty may have resulted from inadequate instructions, especially within this sequencing task that was probably unfamiliar and thus difficult for most subjects. Complete instructions (e.g., instructions about the meaning of the "+") may have resulted in equal acquisition rates for subjects in the OF and SF conditions. Although the experiments reported here were planned to compare the two types of feedback with a minimal role of instructions, this possibility calls for more research on the various effects of instructions on the acquisition of sequential ordering. In any case, because all subjects in these experiments received the same instructions, any misleading effects would be constant across these groups, leaving the obtained differences a likely result of the feedback conditions.

Second, with human subjects, verbal behavior emitted during the experiment should be considered when accounting for differences between subjects. Our postsession interviews were not a very satisfactory source of data, but they provide indications that some subjects named the stimuli and in subsequent trials responded to the stimuli in conjunction with a string of the names they created; other subjects, however, apparently did not. This form of naming and responding to the names could be considered a form of "internal representation," although the location ("internal") is arbitrary. More clarity on the effects of these possibilities could be obtained by replicating these studies using symbols such as stars and circles, or even numbers or letters, which subjects could already name. Comparing the results of the studies reported here with studies using such meaningful stimuli would give some indication about the effect of naming the symbols on learning to arrange sequential orders.

However, naming and responding to self-generated lists of names appear to be activities that can be understood best in the context of the controlling contingencies. As Hayes and Brownstein (1986) explained, in discussing the prediction of one behavior as a result of another behavior such as "a thought,"

> The immediate question (then) becomes what are the determinants of that thought and (even less obviously) what are the contingencies that lead to a relation between a given instance of thinking and overt responding in this individual. (p. 185)

Future investigations into the variables affecting sequential ordering should more closely examine related verbal behavior while continuing to examine the contingencies that establish such relationships; ignoring either would lead to an incomplete account (Hayes & Brownstein, 1986; Skinner, 1974).

Sequential ordering appears to be a useful paradigm for studying the effects of various contingencies on a complex activity. Deitz et al. (1986) showed how small changes in the order of the presentation of stimuli after incorrect responses can produce quite different patterns of acquisition. The present experiments demonstrated that feedback for correct responding is an important component of the contingencies required to produce sequential ordering, and that different types of feedback differentially affect the acquisition of that performance. Phenomena such as the effects of specific instructions about contingencies and the effects of these variables with different types of stimuli and subjects of different ages remain to be investigated.

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