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The Effects of Vocal Instructions and Sequence of Conditions on the Acquisition and Maintenance of Behavioral Chains

Charles L. Lowe
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THE EFFECTS OF VOCAL INSTRUCTIONS AND SEQUENCE
OF CONDITIONS ON THE ACQUISITION AND
MAINTENANCE OF BEHAVIORAL CHAINS

by

Charles L. Lowe

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Doctor of Philosophy
Department of Psychology

Western Michigan University
Kalamazoo, Michigan
August 1986
Five children, ages 5 to 6½ years, were trained to learn and relearn four-link behavioral chains using conditioned reinforcement. Subjects were presented with a horizontal array of 12 chips in four equal groups. During Control Learning (CL) sessions, a new sequence of responses was learned through contingency shaping. The same sequence was presented later that day during a Control Relearning (CRL) session. Instruction on correct responses was provided during Instruction Learning (IL) sessions. The same sequence was presented without instruction during an Instruction Relearning (IRL) session later that day. Thus, new behavioral chains were acquired during CL and IL sessions.

The results of Experiments I and III demonstrated that children can acquire behavioral chains quickly and with few errors when provided with $S^D$ (vocal instructions) for correct responding. Even though instruction was clearly effective in evoking rapid and near error-free acquisition of response sequences, it was not substantially more effective than non-instruction in terms of maintenance of the acquired behavior across time. Reacquisition performance was improved when sequences were acquired without instruction. These findings replicated those of Boren and Devine (1968)
with monkeys, and Peterson (1980), Ozuzu (1982), and Danforth (1983) with children. The present results extend the generality of these findings to a repeated acquisition procedure in which the instructional stimuli were vocal in nature and where the visual aspects of the learning situation remained the same in both instruction and non-instruction conditions.

Experiment II attempted to replicate, within an individual organism design, the findings of Smiley (1974) regarding the effects of vocal instructions. Results of the experiment were inconsistent across the two subjects, and therefore only partially replicated those of Smiley.

This study replicated the effects of vocal instruction on the acquisition and maintenance of behavioral chains while controlling for sequence effects not addressed in previous similar studies.
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ON THE ACQUISITION AND MAINTENANCE OF BEHAVIORAL CHAINS

Western Michigan University

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Lastly, for her faith and confidence, hope and optimism, and love and understanding, I would like to dedicate this work to my wife Pam.

Charles L. Lowe
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A major goal of the experimental analysis of behavior has been the extension of principles of behavior discovered in the nonhuman animal laboratory to human affairs. This goal has been based on the assumption that the principles of behavior discovered with nonhuman animals will be found to be consistent across species. There are numerous reports in the literature which indicate that such cross-species generalities exist. Basic operant research has been conducted with rats and pigeons (Ferster & Skinner, 1957), dogs (Black & Morse, 1961), dolphins (Beach & Pepper, 1972), primates (Kelleher, Gill, Riddle, & Cook, 1963), and other species. In addition, there are numerous instances where basic operant principles, such as positive reinforcement, have been successfully applied to the special problems of the retarded (Lane & Curran, 1963), the mentally ill (Ayllon & Azrin, 1964), and in the area of education (Skinner, 1968). In advocating further application of operant principles to the understanding and control of human behavior, Skinner (1969) has stated that the behavior of humans has been found to be "reassuringly similar" (p. 109) to that observed with nonhumans when the methods of study and analysis have been conducted along lines analogous to those employed in the nonhuman animal laboratory.

In a recent review of the human operant literature, however, Lowe (1978) has argued that results obtained with humans on basic
schedules of reinforcement, such as fixed-interval (FI) and fixed-ratio (FR) schedules, are not reassuringly similar to those observed with nonhumans. The problem is that the patterns of responding obtained by humans on simple schedules of reinforcement differ from those obtained with nonhumans under analogous conditions. Moreover, the patterns of behavior obtained with humans differ across subjects in significant ways (Lippman & Meyer, 1967). The following review examines in more detail a number of the studies giving rise to Lowe's argument.

The Problem

On a FI schedule of reinforcement, the first response after a specified period of time is followed by reinforcement. Nonhuman performance on FI schedules is characterized by a pause in responding after reinforcement followed by an accelerated rate of responding until the next reinforcement (Ferster & Skinner, 1957; Lowe, 1978). Such FI performance has been found to occur in two variants. One cumulative response pattern has been described as scalloping; the other has been described as break and run. Even though the response patterns appear to be quite different, recent research (Branch & Gollub, 1974; Dews, 1978; Lowe & Harzem, 1977) has shown that both types of response patterns are characterized by a gradual acceleration in responding following the post-reinforcement pause. In addition, overall rate of responding declines as a function of increasing interval duration while the post-reinforcement pause and subsequent interresponse times increase as a function of the

As Lowe (1978) has pointed out, similar orderly relations be-
tween FI schedule parameters and responding have not been observed
with adult humans. In contrast to nonhuman performances, those of
humans typically involve high rates throughout each FI interval
(DeCasper & Zeiler, 1972; Leander, Lippman, & Meyer, 1968; Lippman
& Meyer, 1967; Weiner, 1969) or low rates where only a few responses
occur at the end of the interreinforcement interval (Leander et al.,
1968; Lippman & Meyer, 1967; Matthews, Shimhoff, Catania, &
Sagvolden, 1977; Weiner, 1964a, 1969). In addition, adult human
subjects have appeared to be insensitive to the FI parameters noted
previously; variations in schedule value over considerable ranges
have not resulted in appreciable variations in response patterning
or rates of responding (Leander et al., 1968; Weiner, 1969).

The performances of nonhumans and humans also differ on FR
schedules of reinforcement. On a FR schedule, reinforcement occurs
after a fixed number of responses have been emitted. The common
response pattern by nonhumans exposed to such contingencies is a
pause after reinforcement followed by a high rate of responding
until the next reinforcement (Lowe, 1978). Parametrically, the
duration of the post-reinforcement pause increases as a function of
the number of responses required for reinforcement even though the
pause functionally delays the next reinforcement (Felton & Lyon,
1966). Human FR performance, on the other hand, has been notably
different because of the absence of the post-reinforcement pause
despite wide ranges of FR value (DeCasper & Zeiler, 1972; Holland,
Further, the parametric relationship between FR values and response rates observed by Felton and Lyon have not been observed in human operant studies.

The differences in performance between nonhumans and humans on basic operant schedules of reinforcement are important, especially if a single set of learning principles are to be used to account for nonhuman and human operant behavior (Lowe, 1978). Given the orderly parametric relationships between environmental events and nonhuman behavior that have been discovered, an account of the differences in performance must now focus on the determinants of human behavior. Further study of these variables could enhance our understanding of human behavior and may also help account for the species differences in performance described above.

A number of variables controlling human behavior have already been the focus of study. These variables have included the role of response cost or effort; the role of conditioning history; the role of experimenter instructions; and the role of self-instruction by human subjects (Lowe, 1978; Peterson, 1980).

The term "response cost" has been used to refer to the physical effort required in responding and to the loss of previously acquired conditioned reinforcers, such as points on a counter (Weiner, 1962). The rationale for studying the effects of response cost on human operant behavior has been that the effort involved in an nonhuman pressing a lever or pecking a response key is relatively much greater than the effort required by a human to press a response button. The effects of manipulating response cost have been observed in a number
of studies (Azrin, 1958; Leander et al., 1968; Lippman & Meyer, 1967; Weiner, 1962, 1964a, 1965, 1969). In the Azrin study, for example, the pattern of human FI performance was found to change from a high rate of responding throughout the FI interval to a lower rate with a post-reinforcement pause when the force required to press a response button was increased by several hundred grams.

Conditioning history has also been investigated as a determinant of human behavior. There is evidence that whether humans emit high or low rates of responding on FI schedules is at least in part a function of prior history of responding (DeCasper & Zeiler, 1972; Weiner, 1964b, 1965, 1969; Zeiler & Kelly, 1969). Weiner (1965), for instance, has demonstrated such differential effects on FI responding. When humans acquired a history of responding on FR schedules, subsequent FI performance was characterized by a high rate of responding; conversely, a previous history of responding on differential-reinforcement-of-low-rate (DRL) schedules resulted in a low-rate pattern of responding on subsequent FI schedules. Such effects were persistent in that they lasted across sessions and in that sense were mal-adaptive.

At the conclusion of his 1938 work, Skinner (p. 442) suggested that, aside from complexity, the essential differences in nonhuman and human behavior would be found to reside in the area of verbal behavior. Clearly, verbal behavior is a ubiquitous and, perhaps, singularly human achievement. The following studies illustrate the potency and relevance of verbal behavior as a factor influencing human activity.
One line of research has explored the effects of experimenter instructions on subsequent nonverbal behavior in humans. Lippman and Meyer (1967), for example, divided adult human subjects into three experimental groups. One group was instructed that the accumulation of points on a counter involved the number of responses emitted. The second group was instructed that earning points involved the passage of an interval of time. The third group of subjects was given minimal information about the experimental contingencies. All subjects were then exposed to an FI 20-second schedule of reinforcement. The dependent variable was the number and pattern of button presses. Those subjects given the interval instructions subsequently responded at low rates. Two of three subjects given the ratio instructions responded at high rates; the third subject in the group initially responded at high rates but then switched to a lower rate pattern during the session. Ten subjects were given minimal instructions regarding the reinforcement contingency. Four of those subjects responded at a high rate while the remaining six responded in a low rate manner during the fixed intervals.

Similar effects have been reported for variable-interval (VI) schedules of reinforcement. Kaufman, Baron, and Kopp (1966) using a VI 60-second schedule, presented subjects with one of the following sets of instructions: Minimal instructions which provided no information about the schedule; response-based instructions which specified that responses on a key were necessary to produce reinforcement; VI-instructions which accurately described the reinforcement contingency; FI-instructions which specified that reinforcement was delivered on a
FI 60-second schedule; and VR-instructions which indicated that reinforcement would be delivered for every 150 responses, on the average. The effects of the different instructions were clear. Response rates were as low as seven responses per minute for the FI-instructed group and ranged to 269 responses per minute for the VR-instructed group.

As Lowe (1978) has indicated, arguments have been made that humans will show typical schedule performance if experimental subjects are treated more like nonhumans in operant conditioning studies. For instance, Matthews et al. (1977) have argued that if human responding were shaped with minimal verbal instructions as in animal experiments and if the reinforcement contingencies were arranged so that reinforcement delivery required a kind of consummatory response analogous to that present in animal studies, then human schedule performance would more closely resemble that obtained with lower animals. Regardless of the outcome of such experiments, however, verbal behavior remains as a powerful determinant of nonverbal behavior in humans. Even though Skinner (1957, 1969, 1974) has written extensively on the role of verbal behavior in human affairs, it has not been a major focus of study in the experimental analysis of behavior. Methodological problems notwithstanding, the paucity of research investigating the role of verbal behavior and its relation to nonverbal behavior is surprising. A complete account of human behavior must eventually address the issue in an experimental fashion that is consistent with the philosophy and methods characteristic of the experimental analysis of behavior. A somewhat tangential point in this regard concerns attacks on behavioral theory by cognitive psychologists and
psycholinguists. Brewer (1974), as a case in point, has argued that there is no convincing evidence for respondent or operant conditioning in adult humans. A great deal of the weight of the argument rests on the adult human's ability to hypothesize or figure out what he or she would do in a given situation, including operant conditioning experiments, and then respond accordingly.

A clear demonstration of the effects of adult human subjects' verbal behavior on concurrent nonverbal behavior has been provided by Laties and Weiss (1963). In that study, the subjects were required to press an observing response button repeatedly to illuminate a dial with brief flashes of light so that deflections of a needle inside the dial could be detected visually. When a needle deflection was observed, the subjects were allowed 10 seconds in which to respond on a second button to record observation of the deflection and thus earn counter points. The needle deflections were programmed to occur on a FI 100-second schedule based on observing responses. In other words, after an interval of 100 seconds, the next response on the observing button would result in a needle deflection. Under those contingencies, the pattern of responding on the observing button was characterized by a long pause after detection of a needle deflection followed by a high rate of responding until the next detection of a needle deflection. When five of the subjects were subsequently required to perform a concurrent serial subtraction task, however, post-needle-deflection pauses were shortened for some subjects or nearly eliminated for others. Post experiment verbal reports by the subjects were interesting and revealing. All of the subjects reported being aware
of the interval requirement; they reacted to it in a variety of ways, though. During baseline conditions, without the subtraction task, one subject reported that he counted out the interval. When given the concurrent subtraction task, this subject indicated that he attempted to continue counting out the interval but could only do so after the nature of the task was changed in a third experimental condition. Two subjects whose FI performance was least affected by the introduction of the subtraction task reported counting during baseline conditions and then used the size of the remainder in the subtractions as a cue to where they were in the interval. Another subject reported that he did not count during the baseline conditions but, rather, recited a passage from Shakespeare. During the concurrent subtraction task condition he used the number of subtractions performed to estimate where he was in the interval.

As Laties and Weiss (1963) and Lowe (1978) concluded, it is difficult to explain the results of the study without recognizing the controlling effects of the subjects' self-instructions had on their performance. Another point can be made in this regard. It is clear that the subjects adopted simple, sophisticated, and sometimes idiosyncratic methods to determine where they were in the FI interval. While these self-instructions were quite effective during baseline, and in the case of two subjects, during the experimental intervention, they were quite likely typical of the adult human who has a rich and complex verbal repertoire and history, as well as a history in which that verbal repertoire has served as a discriminative stimulus for subsequent nonverbal behavior (Skinner, 1957, 1974). Such a history
and verbal repertoire compounds problems for the researcher interested in studying human verbal behavior and its functional relationship to nonverbal behavior.

Additional empirical support for the role of verbal behavior in determining nonverbal behavior is exclusionary. Lowe, Beasty, and Bentall (1983) shaped human infants to touch a metal drum. The drum touches were reinforced by presentation of music and edibles on FI schedules ranging from 10 to 50 seconds. An analysis of the data revealed that the infants displayed FI responding typical of that observed with nonhumans; that is, the infants' behavior was sensitive to the parameters of the FI schedules. Lowe et al. reported that these results were the first demonstration of such typical FI behavior in humans. The observation that nonverbal human infants responded in a manner similar to nonhumans was cited by Lowe et al. as further evidence for the central role that verbal behavior plays in determining human nonverbal behavior.

Recently, Peterson (1980) has employed a different and potentially very useful method for the further investigation of verbal behavior and its relation to nonverbal behavior. The method employed by Peterson was based on the repeated acquisition procedure originally developed by Boren (1963) and Boren and Devine (1968). The repeated acquisition procedure allows for the investigation of a number of independent variables, including experimenter verbal instructions as well as the acquisition of self-instruction by experimental subjects. In the repeated acquisition procedure, subjects are required to learn a new multiple-response chain each experimental session.
Under such an arrangement, the pattern of learning (acquisition of new response chains) and number of errors to acquisition of the chains reaches a steady state from session to session; hence, a behavioral baseline of relearning is generated against which the effects of independent variables may be assessed. The research reported here was another attempt to employ the repeated acquisition procedure as a means to assess the effects of vocal behavior on nonverbal behavior. In particular, the effects of vocal instructions and sequence of sessions on acquisition and maintenance of behavioral chains were the focus of study. The following review examines the procedure as well as the findings of related previous research.

Review of Selected Literature

Contemporary studies of acquisition or transition phenomena are conceptually and methodologically related to earlier work by Harlow (1949), Polidora (1963), and Sidman and Rosenberger (1967). Harlow argued that the general laws of behavior derived from group design experiments are very limited in their applicability. In contrast to the study of single isolated responses in large groups of subjects, he proposed that the learning of major importance was to be found in learning situations where the organism encountered multiple, though similar, learning problems. Under such conditions it would be possible to study how animals learn how to learn efficiently, or how learning sets are acquired.

In the learning set studies reported by Harlow (1949), monkeys were required to displace one of two stimulus objects which covered
food wells on a tray. The stimulus objects differed in multiple characteristics and were shifted in position, left or right, across trials in a predetermined order. A series of 344 problems using 344 different pairs of stimuli were run on a group of eight monkeys. The first 32 discrimination problems were run for 50 trials; the next 200 problems were run for 6 trials; while the last 112 problems were run for an average of 9 trials per problem.

Harlow (1949) found that the subjects progressively improved in their ability to learn object-quality discriminations efficiently. In other words, the subjects learned new discriminations progressively quicker in terms of percent correct responses across the first six trials of each new problem. The learning curves from the initial problems indicated trial-and-error acquisition of the discriminations while those from the later problems were suggestive of one-trial-learning of the discriminations. The progressive improvement across problems demonstrated in the study defines the concept of learning to learn.

Polidora (1963) employed a sequential-response method to the study of complex behavior and drug effects in rats. The method required the subjects to emit a chain of responses sequentially in space as well as time. The apparatus was a cylinder with four floor-response pedals and stimulus lights located at 90° from each other. The four response locations were designated as A, B, C, and D. Liquid reinforcement was obtained by making responses in a designated order; for example, C, A, B, D. Shaping the behavior required from 5 to 18 one-hour sessions and stable performance in emitting the
sequence was attained in a maximum of 18 subsequent sessions. Polidora found the behavior maintained under the procedure to be sensitive to the detrimental effects of Ditran, a hallucinogenic drug, in terms of percent correct responses. For a given magnitude of behavioral detriment, an inverse relationship between response complexity and dosage was obtained. Response rate alone was observed to remain relatively stable across the chains and doses of the drug.

Sidman and Rosenberger (1967) also studied methods by which serial-position sequences could be taught. They pointed out several reasons why the study of the acquisition of such sequences is useful. First, employing such sequences allows the experimenter to introduce quantifiable levels of difficulty into the study of learning. The difficulty of acquiring a response sequence may be increased simply by lengthening the sequence or number of responses in the behavioral chain. Secondly, once a subject has learned a designated sequence, new sequences can be taught, which allows replication of the learning process within an individual subject. In addition, it is then possible to study changes in the process of learning within the subject as a function of variables such as drugs, methods of instruction, or changes in the organism, i.e., experimentally induced lesions.

In the Sidman and Rosenberger (1967) study, monkeys were required to sequentially press one of three response keys in sequences up to 10 members in length. The response keys, designated A, B, and C could be varied in brightness. To obtain food reinforcement, the monkeys were required to press the keys in a sequence such as: RABCBCACAB. Several methods of teaching the sequences were studied. With fading
procedures, a light that cued the correct key at a given member of the sequence faded out slightly each time the monkey selected it and, conversely, became slightly brighter after the animal made an error at that position in the chain. The fading procedure began with the last members of the serial sequence and proceeded towards the earlier members. In contrast to a control procedure in which the cue lights were turned off suddenly, the fading procedures resulted in the monkeys acquiring a longer series of response sequences.

Sidman and Rosenberger (1967) indicated that their study was methodically similar to earlier work by Boren (1963). Boren's initial report, in abstract form, was followed by a 1968 study with Devine which incorporated aspects of Harlow's (1949) learning-set research and the serial-position studies of Polidora (1963) and Sidman and Rosenberger. In terms of frequency of citation, replication, and application, the 1968 study by Boren and Devine appears to be the prototype of much of the subsequent research in the study of acquisition of learning, or to use Sidman's (1960) phrase, transition phenomena.

In the Boren and Devine (1968) study, monkeys were trained to emit a four-component response chain for food reinforcement. The experimental chamber contained four groups of three response levers arranged in a horizontal line. A small pilot light was located directly above each lever. Following preliminary training, the monkeys were required to learn a new chain each session. The chains consisted of five lever presses on the correct lever in each of the four groups of levers. The monkeys were trained to begin with the left-most group of levers. Five responses on the correct lever in that group resulted in
the pilot lights coming on over each lever in the next group and so on until five responses on the correct lever in the right-most group was followed by food delivery. Incorrect responses at any time were followed by a 15 second timeout (TO) period of chamber darkness. Responses during TO reset the TO interval. Following TO, the pilot lights again came on over the group of levers in which the error had occurred. The procedure resulted in a stable pattern of learning the chains across sessions as reflected in the steady state pattern of errors across sessions and new response sequences.

The study involved two experiments. The first investigated the effects of varying the duration of the TO following an incorrect response. Without TO following an incorrect response, the monkeys made many errors before learning the chains. On the other hand, TO durations of one second to four minutes substantially reduced the number of errors emitted during acquisition of the chains; TO durations exceeding one second were found to be no more effective in reducing errors than the one second duration.

In the second experiment, Boren and Devine (1968) "instructed" the monkeys as to which lever was correct by turning on the pilot light above the correct lever in each group. Thus, in instructed-acquisition sessions, five responses on the correct lever in the first group of levers resulted in the pilot light coming on over the correct lever in the next group and so on until food reinforcement was obtained. Two paired sessions were run for each new response sequence. During the second noninstructed-acquisition session the lights were on
above all three levers in each group, thus eliminating the light cue as to which lever was correct. As a control procedure, a second group of paired sessions was alternated with the first pair of sessions. The first session of the second pair was designated a learning session and was procedurally the same as the noninstructed sessions described above. The second, relearning, session of the pair was also the same. It should also be noted that the sequence of correct levers was also the same for each session of a pair.

The results of the experiment were not uniform across all subjects but were, nonetheless, clear for each monkey. One monkey's responding quickly came under the control of the instructional pilot lights when they were present; the monkey made few errors in acquiring the correct sequence of lever presses. However, when presented the same sequence without the benefit of the instructional stimuli in the second session of the pair, the monkey behaved as if it were learning the sequence for the first time. In contrast, when the subject was required to learn a response sequence without instructional stimuli and was later exposed to the same sequence in the second paired session, again without instructional stimuli, fewer errors were made in the second session, which indicated that the monkey's behavior was under the control of the sequence of correct levers.

Two monkeys failed to follow the instructional stimuli. In other words, the instructional stimuli did not change the number of errors emitted in learning the four-response chain. When tested later without the instructional stimuli, those monkeys made fewer errors as their behavior had apparently already come under the control of the
sequence. In summary, when instructional stimuli controlled responding, with a result of fewer errors to acquisition, the correct sequence was not learned in the sense that it occurred in the absence of the light cues. That finding was evident in the number of errors observed when the monkey was later exposed to the same sequence without instructions. In comparison, when responding came under the control of the sequence of correct levers, as was the case in the absence of instructional stimuli, later testing under the same conditions showed that fewer errors were emitted, thus demonstrating maintenance of learning.

In addition to the findings reviewed above, Boren and Devine (1968) appeared to have developed an experimental methodology which permitted the study of relearning in an individual organism. The technique employed in that research avoided the limitations posed by statistical designs and also addressed the fact that an experimental subject can learn a problem for the first time only once. Consequently, the method permitted the study, in individual subjects, of variables affecting acquisition of behavioral chains.

A subsequent study by Boren (1969) was a further investigation of variables affecting the acquisition of behavioral chains and demonstrated the applicability of the repeated acquisition procedure to the study of superstitious behavior. Boren reported that a large amount of superstitious behavior was emitted by the monkeys in the 1968 Boren and Devine study. The pattern observed was for the subjects to press a random assortment of levers in the early parts of a session before the correct sequence of lever presses was acquired. As
the session progressed, however, a mixture of correct and incorrect responses was noted to occur. Using Boren's example, if the correct sequence of levers was 1-4-8-12, a monkey might be observed to reliably press levers 2-1-4-8-12. The extended chain was reinforced even though presses on lever 2 were unnecessary and, in that sense, superstitious.

The systematic generation of such superstitious behavior within the repeated acquisition procedure was used as a behavioral baseline to study variables affecting its frequency. The subjects were three monkeys with extensive histories of relearning the four-member response chains described above and the experimental chamber and basic procedure was the same as that described earlier (Boren & Devine, 1968). Three experiments were conducted. In the first, the effects of an additional work requirement on the occurrence of superstitious responding was investigated by systematically varying the number of responses required on the correct lever in order to change the pilot lights and to advance towards the end of the chain and food reinforcement. For example, with an FR 10 requirement and the lever sequence 1-4-8-12, the subject was required to press lever 1 at least 10 times before the pilot lights came on over levers 4, 5, and 6, and so on until 10 responses were made on lever 12. The subjects were required to complete the sequence twice for each food delivery. The second experiment investigated the effects of manipulating the consequences of the superstitious behavior. In the earlier Boren and Devine study, it was found that TO's ranging from 1 to 15 seconds following an incorrect response substantially reduced the number of
incorrect responses. However, the TO was programmed such that it included a time delay and a change in the stimulus lights in the chamber; an incorrect response resulted in a time delay and the pilot and houselights in the chamber went out. The purpose of the second experiment was to determine if the delay itself was sufficient to prevent the superstitious chaining of responses by removing the stimulus changes associated with altering the pilot and houselights. That was accomplished by programming a delay between an incorrect response and leaving the pilot and chamber lights on. When the monkey made an incorrect response, a delay was scheduled and further incorrect responses reset the delay. Otherwise, no programmed changes occurred. The third experiment attempted to determine if the superstitious chaining of responses could be reduced by extended training on the same sequences. In that experiment, the subjects were presented with the same sequence of correct levers for five consecutive sessions. Four different sequences were presented, each for five sessions.

The data of primary interest in the first experiment were the performance errors which occurred later in the sessions. When the ratio of performance errors to FR size was plotted as a function of FR size, the main finding was that an increased work requirement resulted in fewer superstitious errors. An analysis of the location of errors within the four-response chain revealed a great deal of variability within as well as across the subjects. Two of the three monkeys, however, made the fewest errors on the link of the chain closest to primary reinforcement, on levers 10, 11, and 12.
The findings from the second experiment were clear in showing that TO delays, regardless of duration, were relatively ineffective in eliminating errors. While the delay alone condition generated considerable variability in the number of errors, none were as effective as a one-second delay with a change in stimulus lights. The substantial difference in effectiveness was explained in terms of the absence of stimulus change occurring under the delay alone condition. The delay alone made poor contact with the incorrect responses. When an incorrect response occurred, no salient stimulus change was forthcoming. The change in stimulus lights, following an error, on the other hand, was immediate and clearly altered the environment. Likewise, when responding continued to occur during the delay alone, both correct and incorrect responses produced no apparent change in the environment. The delay and light changes together were, in comparison, much more exacting in that there were immediate and clear stimulus changes following an error.

With extended training on sequences, Boren (1969) found that the number of superstitious errors progressively declined across sessions. Most of the error reduction occurred during the first two of the five sessions with each sequence. The reduction in errors was suggested to reflect the effects of repeated and consistent reinforcement of correct responding and the effects of the superstitious behavior itself in terms of producing delays and extra responding before reinforcement was obtained.

A study by Hursh (1977) clarified further the nature of the behavioral processes involved in the acquisition of chains. More
specifically, his experiments were designed to separate the enhancing effects of discriminative stimuli from the strengthening effects of differential consequences during the acquisition of the links of a chain of responses. As described earlier, research by Boren and Devine (1968) and Boren (1969) had demonstrated that the rate, or efficiency, with which chains are acquired can be enhanced by presenting a TO associated with stimulus changes following incorrect responses. Such contingencies resulted in significant reductions in the number of errors emitted during the course of acquisition. Hursh's experiments sought to determine the functional nature of such stimuli.

Hursh's (1977) methodology was an adaptation of that employed by Boren and Devine (1968) and Boren (1969). Monkeys were exposed to a stimulus array of two horizontal rows of three response levers. A stimulus light was located above each lever. During preliminary training, each subject earned its entire daily ration of food by correctly emitting a chain of responses on three separate levers. Each trial began with all of the stimulus lights illuminated yellow. A response on any of the levers would momentarily change the associated light to green. The green light was designated as a feedback stimulus. Pressing three different levers in succession produced a food pellet in a lighted cup which terminated the feedback and trial stimuli. Following a brief intertrial interval, in which all lights were dark, the six stimulus lights were again lighted yellow to signal the start of a new trial. A second response to any key during the trial resulted in a 10-second intertrial interval. During baseline, a
different three-key chain was designated as correct each day. A correct response to a key in its designated position in the chain produced the feedback stimuli plus what was referred to as a distinctive stimulus; for example, a white cross on a yellow background. Incorrect responses produced the feedback stimuli alone.

Once repeated acquisition of the chains was stable, test sessions were conducted every third day. In order to assess whether the distinctive stimuli superimposed on the feedback stimuli functioned as conditioned reinforcement, the distinctive stimuli were systematically removed during test sessions. The tests required the removal of one, two, or three of the distinctive stimuli following correct responses, otherwise the sessions were the same as those in baseline. Additional test sessions were conducted in which the distinctive stimuli remained, as in baseline, but either the food or food-cup illumination at the end of a correct sequence of responses was eliminated.

The data from the baseline sessions indicated that the subjects' performance most often made a quick change from no correct chains emitted to consistently accurate performance. Each subject tended to acquire the three members of the chain with near equal accuracy although Hursh (1977) reported that there was a consistent tendency for the first response in the chain to be more accurate than the response just prior to food reinforcement.

The data from the test sessions with distinctive stimuli but no food or food-cup illumination were essentially the same as those from the baseline sessions. Three such test sessions were conducted with
each separated by two baseline sessions. Under those conditions, the chains were acquired without food reinforcement. As in baseline, acquisition of each link of the chain and the entire chain was rapid, as was the tendency for the first member of the chain to be acquired before the third. Test sessions conducted without distinctive stimuli and no food presentation resulted in failure to acquire the chains.

In the test sessions conducted with food presentation and elimination of all distinctive stimuli, acquisition of the chains was severely disrupted. The sessions tended to be much longer and the rate of responding lower than in any other condition. When the distinctive stimuli were removed from only one member of the chain, the overall accuracy of acquisition for all of the members of the chain deteriorated to some degree. The greatest reduction in accuracy, however, was observed on the link of the chain that did not produce a distinctive stimulus, with the exception of the third member of the chain which was followed by food and food-cup illumination.

The observation that chains were acquired rapidly and accurately under the no-food condition with distinctive stimuli indicates that the distinctive stimuli were functioning as conditioned reinforcement for correct responding. Since the designated correct sequence was changed from session to session, stimulus generalization could not account for the acquisition of the new behavioral chains. As Hursh (1977) pointed out, generalization would function to reduce accuracy in procedure, not enhance it. In addition, since elimination of the distinctive stimuli from the first or second members of the chain resulted in a general tendency to retard acquisition of all members, the
distinctive stimuli appeared to have functioned as discriminative stimuli for correct responding. That effect was not nearly as pronounced, however, as the conditioned reinforcement properties of the distinctive stimuli.

In discussing his findings, Hursh (1977) pointed out several aspects of his data that warrant further review. First, he indicated that his results were comparable to the findings of Boren and Devine (1968) and Boren (1969) in that a distinctive stimulus, the TO procedure in those studies, presented after an incorrect response, resulted in a substantial reduction in total errors to acquisition. The comparison of procedures and similar findings is interesting in that the distinctive stimuli followed errors in Boren and Devine and Boren studies, while the distinctive feature was presented following correct responding in the Hursh (1977) experiments. These similar findings suggest a kind of symmetry between the effects of differential punishment for errors and differential reinforcement for correct responses in the acquisition procedures employed. These findings contrast with the usual observation in discrimination training that feature-negative discriminations are more difficult to acquire.

The second aspect of the Hursh (1977) data bearing directly on earlier findings, for example, Sidman and Rosenberger (1967), has to do with the distribution of errors across links of a chain prior to acquisition. The previously reported pattern had been that errors tended to be eliminated first in the link of the chain closest to reinforcement and last in positions more remote from reinforcement. In Hursh's study, where the distinctive stimuli functioned as conditioned
reinforcement for correct responses, similar patterns were not found; rather, the tendency was for the first responses in the chain to be more accurate than those in the link closest to food delivery. Hursh suggested, in light of those findings, that the generalization that chains of behavior develop backward from primary reinforcement may be restricted to situations in which conditioned reinforcement is not available or not presented after correct responses earlier in the chain.

Lastly, Hursh (1977) offered a behavioral analysis of the learning to learn phenomenon (Harlow, 1949). While his analysis was restricted to the observation that the monkeys in his study acquired the chains in the absence of food reinforcement when provided with distinctive stimuli that functioned as conditioned reinforcers, his comments may have broader implication. The acquisition procedure required that the subjects learn a new sequence of responses each session. Even so, the situation was part of the animals' daily routine in which food was obtained. Hence, many aspects of the subjects' behavior could successfully generalize from session to session. For example, the behaviors of orienting, approaching, and pressing keys could contribute to a generalized enhanced efficiency in learning the problem even though they could not, in all likelihood, lead to direct acquisition of that day's new chain. More speculatively, it would seem possible that such effects would contribute more directly to reduced session durations and increased response rates.

In a series of studies, Thompson (1970, 1971, 1973) investigated the parameters of repeated acquisition with pigeons and established
its utility as a behavioral baseline for studying drug effects. The procedure of Boren (1963) and Boren and Devine (1968) was adapted so that in each session pigeons acquired a new sequence of responses. A three-key chamber was used in which the response keys could be illuminated with different colors. During baseline sessions, only response on predetermined keys in the presence of certain colors produced food. For example, with the three keys illuminated yellow, a response to the left key changed the key colors to green. A response to the right key then changed the key colors to red; a center-key response then changed the keys to white and a right-key response produced food.

In the first study of the series (Thompson, 1970), the effects of introducing a tandem probe were studied. Following 40 to 60 baseline sessions, the pigeons were required to correctly emit a new four-response sequence, but without the presence of the different colors. An incorrect response resulted in a 15-second TO during which the response keys were darkened. Errors did not reset the sequence to the initial link of the chain. While correct responses did not produce a change in key colors, there was a slight dimming of the keys, which were white, when the sequence was advanced. After 60 trials on the tandem procedure, the baseline contingencies were reintroduced.

The data from the baseline sessions showed a progressive decline in errors as the session progressed, even though error levels remained above zero. During the probe trials, however, the number of incorrect responses increased significantly compared to the accuracy of responding at the beginning of the previous baseline session.
Reintroduction of the baseline conditions resulted in performance very similar to that of the earlier baseline session. The distribution of errors within the four-response sequence indicated a tendency for fewer errors to occur on the first and fourth links of the chain than in the middle positions. Thompson (1970) stated that the pattern was more apparent under the tandem probe conditions than under the baseline contingencies.

Thompson (1971) further described the pattern of errors across and within sessions. Pigeons were trained to emit four-response sequences on a procedure the same as that described above. The data from the first six sessions showed a substantial reduction in errors across sessions. Up to session 54 and beyond, error levels remained about the same, in a range of 150-350 errors per session. Thompson reported that errors did not seem to be related to the particular response-sequence required with the exception that sequences requiring left, center, right or right, center, left responding tended to be easier to learn. An analysis of within-session errors showed that most errors occurred within the first 20 trials of each session and tended to remain consistent in frequency thereafter. The findings regarding the distribution of errors across the four-link sequence showed no consistent pattern or gradient. The later description differs from Thompson's (1970) previous report and that of Hursh (1977).

Later studies by Thompson (1973, 1974a, 1974b, 1975, 1976, 1977, 1980) demonstrated the usefulness of the repeated-acquisition procedure as a baseline for studying the effects of drugs on errors to
acquisition of sequential chains of behavior as well as the performance of emitting previously learned chains. In a 1973 study, Thompson employed the procedure described earlier (Thompson, 1970, 1971) with one modification: The pigeons were required to emit the correct four-response sequence five times in succession for each food reinforcement; the sequence was changed each session. Approximately 40 to 60 baseline sessions were required before errors per session and within-session error reduction stabilized. Various doses of phenobarbital, chlordiazepoxide, chlorpromazine, and d-amphetamine were then administered across sessions which were interspersed with nondrug sessions. The dose-effect data showed that the drugs, with the exception of chlorpromazine, impaired the accuracy of performance at the doses tested with the degree of impairment, in terms of number of errors, increasing as a function of increased dosage. Chlorpromazine was not found to produce such effects at the doses studied. Each drug increased the amount of pausing. Accuracy was found to be affected at doses that had no effect on rate of responding. The drugs did not seem to have an effect on the distribution of errors within the chains of responses.

Thompson (1975) replicated earlier studies to determine if repeated acquisition of tandem response sequences would be affected by phenobarbital and chlordiazepoxide in the same way that was found with chain sequences (Thompson, 1973). As a means of allowing further comparisons, the procedure also included a performance condition in which chain or tandem response sequences were the same from session to session (Thompson, 1974a). Pigeons were exposed to four different
baseline conditions. Two of the baseline conditions were the same as described earlier (Thompson, 1973): In the chain-learning condition, the subjects were required to learn a new four-link sequence each session in which each member of the chain was designated by a different key color. In the tandem-learning condition, the procedure was the same, but there were no key colors available to designate which member of the chain was present. The chain-performance condition was identical to the chain-learning condition, with the exception that the designated correct sequence did not change from session to session. Likewise, the tandem-performance condition was identical to the tandem-learning sessions except for the unchanging response sequence. Under each condition, five successive correct completions of the chain were required to produce food reinforcement. Dose-effect data were obtained under each baseline condition. Four doses of each drug were tested (5, 10, 20, and 40 mg/kg) with two determinations for each dose and each subject. Drug sessions were separated by five to seven days during which the current baseline conditions remained in effect. Overall, drug testing required 12 to 16 weeks.

The data from the baseline sessions permitted a rank-ordering of the various conditions in terms of total errors per session. The tandem-learning condition resulted in the greatest number of errors, followed by chain-learning, tandem-performance, and chain-performance. The variability in errors per session was greater for the learning conditions than for the performance conditions. Under all four baseline conditions, the largest dose of each drug resulted in decreased accuracy and more errors per session. At the smaller doses,
however, there was differential sensitivity among the baselines to the effects of the drugs. The chain-learning condition was the most sensitive to the drugs in terms of increase in errors. Responding under the performance conditions was relatively constant, though somewhat more errors occurred during drug sessions. The tandem-learning condition was found to be the least sensitive to drug effects, but it was also the baseline condition with the greatest amount of variability in errors across sessions.

The differential sensitivity of the baselines may reflect the differences in stimulus control of responding across the conditions. The response sequence acquired under the chain-performance baseline could be expected to come under strong control of the correlated stimulus lights across sessions. Thompson (1975) likened the performance under the tandem-performance condition as coming under the control of the sequence itself. Under the learning conditions, however, the tasks were more difficult. Since the sequences were changed each session, strong stimulus control by lights or the sequences could not develop. In addition, it should be noted again that the across-session variability in acquisition during the tandem-learning condition was so great as to possibly obscure only major drug effects.

Thompson has employed the procedures described above to test the effects of other drugs and drug combinations on the performance and acquisition of behavioral chains. Those studies include investigations of the effects on acquisition of methylphenidate and imipramine (Thompson, 1976); cocaine (Thompson, 1977); d-amphetamine and chlorpromazine (Thompson, 1980); cocaine and d-amphetamine (Thompson
& Moerschbaecher, 1980); morphine and naloxone; and phencyclidine, pentobarbital, d-amphetamine (Thompson, Moerschbaecher, & Winsauer, 1983). Harting and McMillan (1976a; 1976b) also employed the chain and tandem acquisition procedure described by Thompson (1975) to study the effects of pentobarbital and d-amphetamine on chain acquisition by pigeons. In those studies, however, the addition of a reset contingency, in which incorrect responses produced a return to the initial link of the chain, resulted in fewer errors to acquisition with the reset contingency than without it.

The studies reviewed thus far have been investigations of the effects of various independent variables on the acquisition and performance of sequential chains of behavior. The basic repeated-acquisition procedure described by Boren and Devine (1968) has also been extended to permit the study of the acquisition of complex discriminations and serial acquisition where the reinforcement for responding is avoidance or escape from aversive stimulation.

Moerschbaecher, Boren, and Schrot (1978) developed a procedure in which the repeated acquisition of conditional discriminations could be studied with each subject serving as its own experimental control. In a conditional discrimination, responding is controlled by the relation of the two stimuli as opposed to a single stimulus. The technique used by Moerschbaecher et al. was a discrete-trial procedure in which pigeons were required to correctly emit a two-link chain of conditional discriminations for food reinforcement. Four shapes, a triangle, circle, square, or cross could be superimposed on either a red or green background. The red background was
associated with the first link of the chain. The shapes superimposed on the colors served as discriminative stimuli for either a right- or left-key response. Each trial began with a stimulus combination projected on the center response key; for example, a triangle superimposed on a red background. A response on the center key illuminated two side keys white. The subject was then required to peck either the left or right key depending on the stimulus combination present on the center key. In each link of the chain a particular stimulus combination was the discriminative stimulus for a left-key response, which meant that a right-key response was incorrect. Any other stimulus combination served as a discriminative stimulus for a right-key response, while left-key responses to those stimuli were incorrect. Correct left-key responses advanced the subject to the next link of the chain and the second correct left-key response produced food reinforcement. Incorrect responses on either side key produced a TO period of chamber darkness. The repeated acquisition aspect of the procedure was accomplished by changing the stimulus combination of color and shape for a left-key response each session. Sessions were conducted seven days a week with each session consisting of 60 food reinforcements.

In the first experiment of the study, the length of the TO following incorrect responses was varied to determine if results similar to those of Boren and Devine (1968) would be obtained when the baseline consisted of repeated acquisition of conditional discriminations. At least 14 sessions were conducted with TO durations of 10, 30, 10, 0.25, 10, and 90 seconds, in that order. As was the case with Boren
and Devine and Boren (1969) studies, the stimulus change following errors appeared to be more critical in reducing the occurrence of errors than TO duration, per se. The 0.25-second TO duration was found to maintain performance at levels close to that observed with the longer durations.

The second and third experiments were investigations of the effects of extended training and tandem scheduling on the acquisition of conditional discriminations, respectively. When the discriminative stimuli for a left-key response remained unchanged for three consecutive sessions, errors decreased across sessions but the within-session distributions of errors were unaltered. As appears to be the case in all similar studies, most errors occurred in the beginning of each session and declined in frequency as the sessions progressed.

In the third experiment, the color was removed from the center key at the beginning of a trial, leaving only a geometric form on a white background. Removing the colors, which functioned to designate either the first or second link of the chain, left the subjects with the task of making the correct discrimination on the basis of shape and position in the chain alone; hence, the tandem schedule designation. For three of the four pigeons, errors increased as a function of the tandem procedure. Such findings are similar to those reported by Thompson (1975) in his study of tandem, sequential-acquisition.

In a subsequent study, Moerschbaecher, Boren, Schrot, and Simoes-Fontes (1979) investigated the effects of cocaine and d-amphetamine on the repeated acquisition and performance of conditional discriminations. The acquisition component of the multiple schedule was
essentially the same as that described above in which the pigeons were required to learn a new conditional discrimination each session. The performance component consisted for form-color combinations which remained the same across sessions. The acute effects of the drugs were studied by administering the drugs individually across doses separated by at least five baseline sessions. Chronic drug effects were examined by administering the smallest dose of a drug that produced more errors during acute testing and then increasing the dose across sessions as tolerance developed.

The findings of the study replicated those of Thompson (1975) in that the effects of each drug were more pronounced (increased errors) during the learning or acquisition component of the baseline as compared to the performance component. The differential effects of the drugs on responding in each component were interpreted in light of Thompson's (1975) analysis regarding the limited degree to which stimulus control can develop in an acquisition situation where the task changes repeatedly. The findings also extended the generality of such effects to the acquisition and performance of complex discriminations.

Studies by Schrot, Boren, and Moerschbaecher (1976), Schrot, Boren, Moerschbaecher, and Simoes-Fontes (1978), and Schrot, Thomas, and Banvard (1980, 1981) have demonstrated that sequential reacquisition of behavioral chains can be maintained by avoidance contingencies and food reinforcement in rats.

In the Schrot et al. (1976) study, rats were trained to press each of three response levers in a particular sequence. At the end
of training, the beginning of each session was signalled by illumination of the chamber houselight and the onset of auditory clicks at the rate of five clicks per second. If the animal did not respond or pressed the incorrect lever of the three, shock was delivered via the floor grid. The first correct response reset the shock-shock (SS) cycle, which was either 10 or 20 seconds, advanced the sequence, and increased the click rate. Likewise, the second correct response advanced the sequence, reset the SS cycle, and further increased the click rate. The third correct response produced a signalled-TO from the shock-avoidance contingencies during which the chamber was darkened and the clicks stopped. Shock was never administered during TO. At the end of the TO period, the procedure recycled to the conditions in effect at the first member of the chain. Sessions ended when the sequence of three correct responses had been emitted 350 times or after 750 shocks. The independent variable was the duration of the TO period, which was varied from 1 to 120 seconds with each TO duration in effect for a minimum of 12 sessions. Four different response sequences were presented, one each session. The sequences were 1-3-2, 2-1-3, 3-1-2, and 2-3-1.

The baseline avoidance contingencies generated a stable pattern of sequential reacquisition within and across sessions. Within sessions, performance, in terms of accuracy of responding, improved most during the first 200 sequences and reached stable levels during the final 150 sequences. The pattern of within-session acquisition is in agreement with that reported with food reinforcement with monkeys (Boren & Devine, 1968) and pigeons (Thompson, 1970).
Variations in TO duration were found to exert control over baseline performance. At intermediate durations (15, 30, and 60 seconds), the rats completed the sequences more quickly and received fewer shocks. Errors, however, were not found to vary as a function of TO duration. The authors suggested that the relative insensitivity of frequency of errors to differing TO durations may have occurred as a result of a lack of immediate consequences for incorrect responding. In other words, an incorrect response started a response-shock interval (10 or 20 seconds) where the consequence for the error would be temporally delayed for some time. Such an analysis would appear consistent with Boren's (1969) and Hursh's (1977) earlier findings regarding the importance of immediate stimulus changes following errors and subsequent reductions in the frequency of errors during acquisition.

As appears to be the case with other variations on the sequential reacquisition procedure of Boren and Devine (1968), the shock-avoidance procedure described above was employed by Schrot et al. (1978) as a baseline to investigate the effects of cocaine and d-amphetamine on acquisition.

The findings of that study were consistent with those reported by Moerschbaecher et al. (1979) and Thompson (1973, 1974b, 1977) regarding the effects of cocaine and d-amphetamine on food maintained acquisition of behavioral chains. In all of the studies, both drugs at higher doses resulted in an increase in errors. The drugs appeared to disrupt the common pattern of biphasic acquisition seen in baseline sessions; errors did not decrease in frequency during the later
parts of each session when drugs were administered at high doses.

One exception with shock-maintained responding was that decreases in response rate, per se, did not occur. Schrot et al. (1978) attributed the result to the observation that shock presentation produced bursts of responding, even though more of the responses, under drug conditions, were errors.

Schrot et al. (1980, 1981) described a repeated acquisition procedure for use with rats in which responding was maintained by food reinforcement. Their procedure was similar to that developed by Thompson (1970) for use with pigeons. A three-lever response chamber was used in which auditory, as opposed to visual, stimuli signalled each member of the chain. Following training, the subjects were required to correctly complete a four-link chain on the three levers to obtain food pellets. The first member of the chain was signalled by 900-Hz tone. A response to the correct lever of the three for the first link produced clicks at a rate of one per second. A second correct response then advanced the sequence to the third member and produced a 2000-Hz tone. The next correct response produced clicks at a rate of 10 per second. The fourth consecutive correct response resulted in food delivery and offset of the auditory stimuli for 1.5 seconds before the cycle repeated. Incorrect responses were followed by a three-second TO during which the chamber light was darkened and the auditory stimuli stopped. Incorrect responses did not return the subjects to the initial link of the sequence. While the ordering of the auditory stimuli were the same from session to session, the sequence of correct levers was changed.
Seventy to 90 sessions were required before responding stabilized. The patterns of acquisition obtained, in terms of within-session error reduction, were comparable to those reported previously by Boren (1969), Boren and Devine (1968), and Thompson (1970, 1971). The pattern of learning to learn across sessions was observed as well. The minimum error levels following stability in the acquisition process were reported to remain constant for over one year. A further analysis of the pattern of within-session errors showed that perseverative responses to a single lever or traverses, in which a response to each lever in a left-to-right or right-to-left direction occurred, accounted for between 50 and 70% of all errors. The authors also reported that the subjects started every session by making about the same number of traverses whether the sequenced reinforced traversing or not. In sessions where traversing was not reinforced, the behavior diminished as the session progressed but never ceased entirely. Generally, the type of sequence, i.e., one requiring a traverse or not, was not related in any orderly manner to the frequency of errors.

Recently, a number of repeated-acquisition studies have been conducted in which children have served as experimental subjects. The studies with children have been attempts to utilize a repeated-acquisition baseline as a means of investigating the acquisition of rule-governed behavior (Peterson, 1980); the effects of rule-stating on acquisition (Ozuzu, 1982); and the effects of verbal instructions on acquisition (Danforth, 1983).

In Peterson's (1980) study, preschool-age children were taught to emit a four-response chain using points as conditioned...
reinforcement. The points were later exchanged for small toys or trinkets. The children were presented with an intelligence panel composed of four groups of three push buttons arranged in a horizontal array. A pilot light was located directly above each button. In addition, a point counter was centered above the button and light array.

Experiment I of the Peterson (1980) study was described as an attempt to replicate the second experiment of Boren and Devine (1968) by presenting a light (instructional stimulus) over the correct response button in each group of three to determine the light's role in facilitating the acquisition of the correct response sequence. As with the Boren and Devine procedure, the designated correct sequence of buttons was changed each session. Peterson found that in the absence of the instructional stimuli, the children made many errors before responding came under the control of the correct sequence of buttons (Control Learning Phase). When presented with the same conditions and sequence later in the day (Control Relearning Phase), the children made fewer errors before reaching a criterion of five correct response sequences without error. In comparison, when presented with instructional stimuli over the correct buttons (Instructional Learning Phase), the children made virtually no errors in the course of acquisition to criterion. When the instructional stimuli were removed during a session later that day (Instructional Relearning Phase), the children made many errors before the sequence was acquired, even though the sequence was the same.
In Experiment II, Peterson (1980) required the children to describe the contingencies of reinforcement during the Control-Learning sessions to determine the effects such description would have on the number of errors to acquisition in the Control Learning and Control Relearning sessions. The children were required to tell the experimenter which button they were going to press in each of the four groups and, at the end of the sessions, what the correct response sequence was for that day. Peterson found that when the children were required to verbalize the contingencies in Control-Learning, almost no errors occurred during Control-Relearning, but errors continued to occur during Instructional Relearning. Two of the five subjects were also required to verbalize the sequence in Instructional Learning sessions. The requirement did not, however, change the error rate during Instructional Relearning. Peterson's findings were similar to Boren and Devine's (1968) in that subjects who followed instructional stimuli were able to acquire a correct sequence with few errors. The acquired behavior, however, was not well maintained over time. In addition, the children in the study appeared to make progressively fewer errors across sessions until a stable minimum level of error was reached. The pattern of learning to learn is consistent with that observed with nonhumans (Boren & Devine, 1968; Schrot et al., 1980, 1981; Thompson, 1970, 1971). The within-session distribution of errors across the links of the chain was reported to show a tendency towards acquisition of the first and last links before the middle links of the chain.
In a partial replication of Peterson's (1980) study, Ozuzu (1982) attempted to arrange for the transfer of control of responding from the instructional stimuli to the correct sequence itself by fading the presence of the instructional stimuli. In Ozuzu's research, preschool-age children were taught to emit a five-response sequence which consisted of picking up a poker chip in each of five groups of three chips. The children worked for points on a counter which were later exchanged for money. The experimental design was similar to that used by Boren and Devine (1968) and Peterson. Each experiment was composed of six blocks of two paired sessions. The first session of each day was an acquisition session in which a new five-response chain was learned. On the first day of a block, a morning acquisition session was conducted in which the children learned the behavioral chain without instructional stimuli. An afternoon reacquisition session was conducted under identical conditions. On the second day of a block of sessions, the morning session was an instructed acquisition session in which the correct chip was displaced in each group, thus providing an explicit instruction as to which chip was correct. The afternoon session of the second day of a block was an un instructed-reacquisition session which was procedurally identical to the morning session, except that the chips were not displaced.

Under the conditions described above, Ozuzu (1982) found that instruction resulted in learning without errors but, when tested later with the same sequence, many errors occurred during un instructed-reacquisition sessions. Thus, Ozuzu's results replicated those obtained by Boren and Devine (1968) and Peterson (1980): Instruction,
when followed, resulted in near errorless acquisition of behavioral chains but did not result in maintenance of acquisition across time as in the case when the chains were acquired through contingency shaping, which produced many errors.

In a second experiment, Ozuzu (1982) faded the instructional stimuli across trials within the instructed-acquisition sessions by gradually moving the displaced chips back into line with the other two chips in each group. Fading resulted in performance during uninstructed-reacquisition sessions that was only marginally better than performance, in terms of number of errors, observed in the uninstructed reacquisition sessions of the first experiment. When Ozuzu superimposed a rule-stating requirement on the fading procedure by requiring the subjects to state which chip they were going to pick up, whether it was the correct chip and, after the session, what the correct chip sequence was, he again did not find improvement in acquisition in later uninstructed reacquisition sessions.

Danforth (1983) has also attempted to isolate variables which may result in transfer of stimulus control of responding from instructional stimuli to response sequences. The value of isolating such variables lies in the possibility of engendering rapid, near errorless acquisition while at the same time providing for maintenance of the acquired behavior across temporal distances. Or, in other words, determining what conditions constitute effective instruction.

The children in Danforth's (1983) study were taught to emit four-response chains in a manner similar to that required of the children in Ozuzu's (1982) study. In Experiment I, Danforth obtained results
similar to those of Boren and Devine (1968), Peterson (1980), and Ozuzu (1982), regarding the effects of providing instructional stimuli on acquisition. In Experiment II, Danforth attempted to determine if limited instruction would improve reacquisition performance. Instructional stimuli, in the form of markers above the correct chip in each group, were removed after two consecutive response sequences were emitted without error during instructed-acquisition sessions. The finding was fewer relearning errors in uninstructed reacquisition sessions; however, the procedure required more morning learning trials and the benefit of rapid acquisition was lost. The children were then taught a verbal rule relevant to the instructional stimuli. Specifically, the children were required to state a rule indicating that the correct chip was under the instructional stimulus in each group and that once the instructional stimulus was removed, the correct chips remained the same. Danforth reported that the combination of limited instruction and rule-stating was no more effective in producing acquisition and maintenance of the four-response chain than the acquisition evoked by contingency shaping in the uninstructed-acquisition sessions.

In a third experiment, Danforth (1983) instructed one child that the morning and afternoon sessions were identical. During the initial sessions in which such instruction was provided, the frequency of errors in the afternoon uninstructed sessions remained stable. The subject then missed approximately two weeks of experimental sessions. When he returned, the subject was again exposed to baseline conditions of paired uninstructed acquisition/uninstructed
reacquisition and instructed acquisition/uninstructed reacquisition sessions. At that point, the subject began emitting fewer errors in the afternoon sessions even though approximately two weeks had passed since the subject last heard the sequence-similarity rule from the experimenter.

To summarize, it appears that the repeated acquisition procedure provides a baseline of acquisition that is sensitive to the effects of a number of variables. It is also apparent that investigators (Boren & Devine, 1968; Danforth, 1983; Ozuzu, 1982; Peterson, 1980) using a form of the procedure to assess the effects of instructions on acquisition and maintenance of behavioral chains have yet to discover independent variables which functionally provide the benefit of rapid acquisition with few errors in addition to the maintenance of acquisition generated by contingency shaping. These findings are in conflict with those reported by Smiley (1974) who employed a different method to investigate the roles of experimenter instructions and the subjects' own verbal behavior on the acquisition of chains of behavior.

In the Smiley (1974) study (Experiment III), preschool-age children acquired behavioral chains in a guessing game situation. The apparatus was a board on which five columns of pictures were presented. The pictures in each column were, from top to bottom, of a pig, a hat, and a boy. The children were required to guess and indicate with binder rings which picture in each column the experimenter was thinking of. Correct responses were reinforced with plastic chips which were later exchanged for toys. Incorrect responses were
followed by a TO procedure. All of the subjects (N=30) were given the following set of instructions:

Look at these pictures. There is a pig and a hat and a boy. I will tell you the name of one of the pictures and I want you to put this ring around the one that I say.

In addition, one half of the children were told the following:

Listen carefully to what I say. This time I am going to tell you where to put the ring, but the next time you will have to remember where to put the ring. I'll only tell you one time where to put the ring, then you'll have to do it yourself. Listen.

The session then continued until each subject identified the correct sequence of pictures without error on five consecutive trials. Smiley found that the subjects given the additional instructions regarding the pending change in the task emitted fewer errors to criterion than those given only the first set of instructions.

It is puzzling that the findings of Peterson (1980) and Ozuzu (1982) differ from those obtained by Smiley (1974). The single subject given the sequence-similarity rule in Danforth's (1983) study performed in a manner consistent with the children given additional instructions in Smiley's study, but why is not clear, especially given the apparent lack of immediate effect of the rule and the two-week absence before returning to the experiment and following the rule. Attempts at replication appear warranted, particularly in regard to the effects of verbal instructions on the acquisition and maintenance of behavioral chains. As Michael (1984) has pointed out, repeated acquisition procedures may serve as useful baselines for the study of verbal behavior as well as the effects of verbal instructions on
nonverbal behavior.

Two studies appear in the literature in which repeated-acquisition of sequences by humans have served as baselines against which drug effects have been examined. Walker (1981) presented adult males with an apparatus that contained a single digit display, a session light, a row of 10 indicator lamps, and a point counter. In addition, a separate box contained three touch-sensitive switches. Experimental sessions began with presentation of the number one on the digit display. After a 10-second delay, the first stimulus lamp was lighted and the subject pressed one of the switches. Within each session, each of the 10 lights was associated with one of the switches. Each correct response illuminated the next light. Every fifth completion of the sequence added 10 points to the counter. Incorrect responses turned off the light for two seconds. Responding during TO had no effect. Following TO, the light on which the error occurred was re-illuminated, thus, the completed sequences did not have to be error free. Two individual 15 minute sessions were conducted each experimental day with the sessions separated by 5 minutes. The sequence of correct responses was changed each session.

During a preliminary training period of 12 experimental sessions, no drugs or placebo were administered. Subsequent sessions were conducted two hours after administration of placebo or doses of 5, 10, or 15 mg of d-amphetamine. Drug sessions were separated by a minimum of two placebo control sessions.

Walker (1981) reported that acquisition of the response sequences was characterized by a decrease in errors and an increase in
response rate, which was maximal at 10 mg of d-amphetamine. Walker's findings differ from those reported by Thompson (1973, 1974b) with pigeons in which d-amphetamine resulted in an increased number of errors during acquisition, at least at the higher doses tested. Walker suggested that the variance in findings may reflect species differences in response to the drug and/or the procedural variations across the studies.

In a study involving children diagnosed as hyperactive, Yoder (1984) assessed the effects of different doses of methylphenidate (Ritalin) on the learning and performance of response sequences. The children, ranging in age from 6 to 11, were presented with an array of 18 poker chips divided into six groups of three chips each. Each session was comprised of an acquisition (learning) component and a performance component. During the acquisition part of the session, the children were required to pick up a chip, sequentially from left to right, in each of the six groups. If the subject picked up the correct chip, the sequence was advanced by the experimenter moving a bar over the next group of chips. Errors resulted in a five-second TO during which the array was covered. Following the TO, the subject resumed the task with the same group of chips. Completion of the sequence resulted in the addition of one point to a digital counter; errorless completion of the sequence produced two points. The sequence of chips was changed daily during the acquisition component. The performance component of each session was the same, with two exceptions. The poker chips were different in color from those used during acquisition and the designated correct chip sequence remained
the same across sessions. The components ended after 10 minutes or 20 completions of the sequences. The points earned were exchanged for arcade tokens or dimes.

The morning dosage of methylphenidate was varied across sessions for each subject. The doses tested were based upon each subject's previously determined therapeutic dose of the drug, which served as the baseline value of the independent variable. Across sessions each subject was administered the baseline dosage; a dosage five mg higher than baseline; a dosage five mg lower than baseline; and placebo. Each dosage was administered for a minimum of one week.

Yoder (1984) reported that methylphenidate produced no effect on either the number of errors per session or on the rate of responding at the dosages tested. The variability of errors was about the same within and across the various dosages for both the learning and performance components of the study. Compared to the performance component, variability across acquisition components was high. An additional measure, teachers' ratings of social behavior, showed that teachers rated the children as less hyperactive as the amount of medication was increased. The teachers were, of course, blind to the variations in methylphenidate.

The results obtained by Yoder (1984) differ from those reported by Thompson (1976) on the effects of methylphenidate on acquisition and performance of behavioral chains by pigeons. Thompson found that errors per session in both learning and performance components of his study increased as a function of dose with lower doses affecting acquisition but not performance of the response sequences.
There would appear to be many plausible reasons for the variance in findings in the effects of drugs on humans and animals. Species differences in response to a drug would seem an obvious possibility as would procedural differences. Research with human subjects requires experimental considerations and limits not required in work with lower species. Generally, the range of variability in baseline levels of acquisition errors tends to be greater than that seen with animals. Such differences may speak to the fact that animal research is not subject to the same time limitations as human research in many instances. Animal researchers conduct extended training and baseline phases as a means of assuring stability in performance before investigating the effects of independent variables. Human research often does not permit similar latitude. In addition, research with humans introduces the consideration that verbal behavior may play an important role in experimental outcome. The nature of the reinforcement employed may be very important as well. Many animal subjects obtain a significant amount of their daily ration of food during experimental sessions. The reinforcement used in human research, while demonstrably effective in strengthening behavior, is primarily conditioned reinforcement. Nonetheless, the repeated acquisition studies reviewed here demonstrate the generality of behavioral processes across species, in some instances with considerable agreement of findings; for example, the similar findings of Boren and Devine (1968) and Peterson (1980).

The original reports by Boren (1963) and Boren and Devine (1968) of a method which allows the study of repeated acquisition of
learning within single subjects has been followed by studies investigating the parameters of variables affecting such acquisition. At a general level of analysis, the procedure, and variations on it, has been shown to be applicable to monkeys (Boren & Devine, 1968), pigeons (Thompson, 1970, 1971), rats (Schrot et al., 1980, 1981), and humans (Danforth, 1983; Ozuzu, 1982; Peterson, 1980; Yoder, 1984). In terms of application, repeated acquisition baselines have been employed most frequently to assess the effects of drugs (Harting & McMillan, 1976a, 1976b; Thompson, 1973, 1974a, 1974b, 1975, 1976, 1977, 1980; Thompson & Moerschbaecher, 1980, 1981; Thompson et al., 1983; Walker, 1981; Yoder, 1984). The various studies clearly indicate that the behavior maintained on such procedures is sensitive to the effects of a variety of drug compounds. The studies by Moerschbaecher et al. (1978), and Moerschbaecher et al. (1979) have demonstrated that the processes involved in the acquisition of complex discriminations can be investigated within repeated acquisition procedures. The recent studies with human subjects, particularly young children, by Peterson, Ozuzu, and Danforth are interesting in view of the nature of the independent variables studied. Repeated acquisition baselines may prove very valuable in efforts to understand the effects of, and possibly acquisition of, certain types of verbal behavior. As Peterson has pointed out, young children are especially interesting subjects because they often possess only the beginnings of the human verbal repertoire. Such subjects may provide a means of assessing the effects of different types of instruction on learning. Differences and similarities among visual, vocal, and auditory
instructional stimuli may be productively studied within repeated acquisition baselines. It would seem important, however, to initially explore the parameters of the procedure with humans. For example, a detailed examination of error distributions during acquisition under chain and tandem conditions or the distribution of errors under acquisition vs. performance conditions.

Several conclusions seem possible with regard to the specific findings across the studies reviewed. First, the pattern of acquisition of response sequences appears to be biphasic. Many errors occur early in acquisition sessions followed by an abrupt acquisition of the sequence where relatively few errors occur. Boren (1969) termed the former as learning errors and the later as performance errors. While differences have been reported among the studies, the distribution of errors within the response sequences has tended towards a pattern in which the first and last links of the chain are acquired before the middle members. The distinctive nature, to use Hursh's (1977) term, of reinforcement following completion of the last link in the chain serves to more immediately strengthen that response as well as function as a salient discriminative stimulus for the next, first, response of the chain. Thompson's (1971) report that such a tendency was more apparent under tandem conditions would seem to support such an analysis.

Differential consequences for either errors or correct responses appear to be a critical factor in the efficient acquisition of behavioral chains. As a variable, TO duration, per se, following errors has not been shown to be an effective means of reducing the number of
errors to acquisition. The studies by Boren and Devine (1968), Boren (1969), Thompson (1970, 1971), and Hursh (1977) have shown that TO must be accompanied by a stimulus change which has immediate environmental effects to be effective. Additional support for this conclusion comes from the study by Schrot et al. (1976) in which the duration of TO from avoidance contingencies had no effect on the frequency of errors during acquisition. Even with effective TO contingencies, however, errors during acquisition sessions fall to a minimum level but continue to occur across sessions. Thus, while the phenomenon of learning to learn (Harlow, 1949) is observed across sessions and different response sequences, a minimal level of error remains. The baseline of errors is, however, sensitive to the effects of a variety of variables.

The research presented here was an attempt to further investigate the effects of instruction on the acquisition and maintenance of chains of behavior. In addition, the order in which experimental sessions were conducted was varied for some subjects in an attempt to determine if previous findings were possibly an artifact of the experimental designs.

A common feature of the Peterson (1980), Ozuzu (1982), and Danforth, (1983) studies was that each employed a visual instruction stimulus, either in the form of lights, displaced chips, or an additional marker. It may have been the case that the presence of such visual instructional stimuli mitigated against the effects of further instruction. Experiment I, in the present study, was an attempt to address this possibility and to further define the
parameters of what constitutes an instructional stimulus within the confines of the repeated acquisition of behavioral chains. Using a repeated acquisition procedure and subjects similar to those employed by Peterson, Ozuzu, and Danforth, the effects of vocal instructional stimuli on the acquisition and maintenance of behavioral chains was assessed. Experiment II was an investigation of the effects of providing a limited set of vocal instructions on the acquisition and maintenance of chains. The instructions were modeled after those used by Smiley (1974) who reported that they were effective in engendering acquisition and maintenance of behavior, a finding which, as discussed previously, differed from those reported by Peterson, Ozuzu, and Danforth. Experiment II may also be considered an attempt to replicate findings from a group design in a procedure in which each subject serves as its own experimental control.

Another common aspect of the Boren and Devine (1968), Peterson (1980), Ozuzu (1982), and Danforth (1983) studies was the manner in which the experimental sessions were arranged. In each of the studies, uninstructed acquisition/uninstructed reacquisition sessions were paired with instructed acquisition/instructed reacquisition sessions. The uninstructed acquisition, uninstructed reacquisition, and instructed reacquisition sessions were the same in terms of the stimulus conditions present at the beginning of each session; only the instructed acquisition sessions differed in the immediate presence of the instructional stimuli. Since the same sequence of responding was reinforced in the consecutive uninstructed acquisition/uninstructed reacquisition sessions, the subjects could be expected to respond
with a similar tendency when presented with the same initial stimulus conditions in the instructed reacquisition session. Such a tendency might then function to increase the number of errors during the instructed reacquisition sessions. If this were the case, the results would suggest, as has been the case in previous studies, that instructional stimuli do not result in acquisition and maintenance of chains of responses. Experiment III was an attempt to control for this possibility by conducting the uninstructed acquisition/uninstructed reacquisition sessions in one consecutive series followed by an equal number of instructed acquisition/instructed reacquisition sessions. The experiment, then, was an attempt to replicate the effects of vocal instruction on the acquisition and maintenance of behavioral chains, but with a control for possible sequence effects not addressed in previous similar studies.
METHOD

Subjects

Five children, four boys and a girl, participated in the study. At the beginning of experimentation, the children ranged from five to six and one-half years in age. The children were selected from the population of the Child Development Center in Kalamazoo, Michigan. Participation in the study was contingent on documented informed consent by the parents of each child. The study was approved by the director of the preschool as well as the Human Subjects Review Committee at Western Michigan University prior to selection of the subjects.

Apparatus

The intelligence pad was composed of brown corrugated paper board and measured 81.0 by 10.6 cm. Twelve plastic poker chips measuring 3.8 cm in diameter were fixed to the pad in a horizontal array. The chips were arranged into four groups of three chips each. Within each group, viewed from the subjects' perspective and starting from the left, one chip was red, one chip was white, and one chip was blue in color. The individual chips in each group were separated, adjacent edge to adjacent edge, by a distance of 1.2 cm. A distance of 8.1 cm separated each adjacent group of chips. A black wooden dowel 13.7 cm in length was used as a discriminative stimulus bar. The bar was located in a groove in the pad 3.1 cm above the
top-most edge of the chips, and could be moved by the experimenter so that its length extended across the three chips in each group.

A second piece of board, measuring 80 by 10.6 cm, was connected along the top-most edge of the pad and functioned as a TO screen. By folding the TO screen over the pad the array of chips was covered. Six paper index cards, each measuring 7.7 by 12.8 cm, were arranged in a flip-chart manner. The cards, which served as a point counter, had the number 0, 1, 2, 3, 4 or 5 printed on one side in heavy black line. A variety of paper and plastic stickers were used as conditioned reinforcers.

The sessions were conducted in a room with only the subject and experimenter present. The subject and experimenter sat side by side at a low table on which the intelligence pad and point counter were placed. The data were collected manually by the experimenter.

Procedure

Preliminary Training and General Procedure

Prior to the start of the experiment, the subjects were tested to determine their skill at accurately responding to the various colors of the chips. Individually, each subject was seated at a table alongside the experimenter. One red, one white, and one blue chip was placed on the table in front of the subject. Over a series of 12 trials, the experimenter said to the subject, "Touch the (color) chip." Each color was named by the experimenter on four separate trials. Between each trial the arrangement of chips was varied so that the sequence of colors varied from trial to trial. A criterion
of 100% accuracy on the 12 trials was required for a subject to participate in the study.

In order to determine if shaped responding or verbally directed training had differential effects on later performance, two subjects were exposed to a shaping procedure. The remaining subjects were verbally directed regarding the experimental task.

Directed Procedure

The subjects exposed to the directed procedure were read the following instructions:

Look at this board and chips. Touching certain chips like this (Experimenter touches a chip) will earn points on this counter (Experimenter demonstrates how the flip chart counter works). This bar will tell you which group of chips to work with (Experimenter moves the discriminative stimulus bar from one group of chips to another). When we are done, you can trade your points for the prize you picked earlier. If you touch a wrong chip, a cover will be placed over the chips. It is up to you to touch the right chips to earn points. Touch only one chip at a time. Do not begin until you are told to start.

No further instructions were provided to the subjects. If a child did not respond or asked questions, the experimenter said, "It is up to you to figure out what to do." The rationale for requiring the subjects to touch the chips, as opposed to picking them up as in previous studies (e.g., Danforth, 1983; Ozuzu, 1982) was that touching did not alter the physical configuration of the stimulus array.

For those subjects exposed to the directed procedure, each session began with the discriminative stimulus bar over the left-most group of chips. Touching the designated correct chip in that
group resulted in the bar being moved over the next group of three chips and so on until the correct chip was touched in the right-most group of chips. One point was added to the counter when the correct sequence of chips was touched in order without an error of touching an incorrect chip. Touching an incorrect chip at any time resulted in the TO screen being placed over the array of chips for five seconds. Once the screen was removed, the trial resumed with the same group of chips in which the error occurred. In addition, any previously acquired points were lost and the counter set to zero. The preliminary directed training sessions terminated when the correct sequence of four chip touches was emitted five consecutive times without error. The child was then given the previously selected toy or trinket. The subjects exposed to the directed procedure were given three practice sessions prior to the start of Experiment I. The sequence of correct chips was varied across sessions.

**Shaping Procedure**

The shaping process was conducted in a manner similar to that employed by Peterson (1980), Ozuzu (1982), and Danforth (1983). The shaping procedure consisted of six steps:

**Step 1.** The experimenter read the following instructions to the subject:

*The work you do here will earn points on this counter (Experimenter points to the counter and explains how it works). At the end of our meeting, you can trade your points for the prize you picked earlier. The way to earn points is to touch certain chips like this (Experimenter*
No further experimenter instructions were provided. If the child did not respond or asked what to do, the experimenter said, "It is up to you to figure out what to do."

**Step 2.** The subject earned one point on the counter for touching any of the chips. The step was completed when the subject responded on five successive occasions to at least five different chips.

**Step 3.** The experimenter placed the wooden discriminative stimulus bar over one of the groups of chips. One point was added to the counter if a chip below the bar was touched. Touching a chip from any other group resulted in a five-second TO period during which the screen was placed over the array of chips and the point counter was set to zero. The wooden bar was moved randomly from one group of chips to another until its placement reliably controlled the responses of the subject.

**Step 4.** In this step, points were contingent on a chain of responses to the chips. The experimenter placed the wooden bar over the third group of chips from the left. A response to one of the chips in that group resulted in the bar being moved to the fourth group of chips. A response to one of the chips in the fourth group resulted in the addition of one point to the counter. Once that response sequence was emitted five times consecutively without error, the procedure was altered to begin with the second group of chips. When criterion was met with that sequence, the first group of chips was added to the sequence. During this step of training, incorrect responses resulted in a five-second TO, after which the trial resumed.
with the same group of chips.

**Step 5.** During this step, only a response to a predetermined chip in each group of chips resulted in the discriminative stimulus bar being moved to the next group of chips. Any other response resulted in a five-second TO, followed by another trial with the same group of chips until the correct chip was touched. Points were contingent on touching the correct chip in each group in sequence; that is, the entire sequence of correct chips had to be touched in order to earn one point. This step was completed when a criterion of five consecutive correct response sequences, without error, were emitted in three consecutive sessions.

**Step 6.** This step was the same as Step 5 except that the sequence of correct chips was changed from session to session. A list of correct chip sequences was prearranged so that no single sequence appeared two days in a row. In addition, simple ordering of sequences was avoided, such as the first chip in each group being designated as correct.

In summary, at the end of the preliminary training, all subjects learned a new four-response chain each day. The subjects touched a chip in the left-most group of chips. If the predetermined correct chip was touched, the discriminative stimulus bar was moved to the next group of chips, consecutively, until the bar was placed over the fourth group of chips. One point was added to the counter when the correct chip in each consecutive group was touched. An incorrect response at any point resulted in a five-second TO period, followed by further trials with the same group of chips until the correct
chip was touched. The wooden bar was then moved to the next group of chips. Sessions ended when the correct sequence of responses was emitted five times consecutively without error. At that point, the subject was given the previously selected prize. The criteria for ending sessions, the TO procedure, and the method for selecting sequences of correct chips remained unchanged for the duration of the study. Session data included the number of errors; the number of learning trials, a trial being defined as the completion of the four-response chain, regardless of errors; and session duration.

**Experiment I: Effects of Vocal Instruction Stimulus**

The procedure of Experiment I was similar to that employed by Boren and Devine (1968), Peterson (1980), Ozuzu (1982), and Danforth (1983). In those studies, the effects of adding visual instructional stimuli on the acquisition and maintenance of behavioral chains was investigated. The results of the studies were uniform in that the presence of an instruction stimulus resulted in fewer errors to acquisition of the behavioral chains, compared to the number of errors to acquisition without the benefit of an instruction stimulus. However, when exposed to the same sequence in a later session without the instructional stimuli, subjects emitted errors in a manner as if they were learning the sequence for the first time. In contrast, when the subjects learned a sequence to criterion without instructional stimuli, their later performance with the same sequence, again without instructional stimuli, was characterized by fewer errors than was observed during the earlier sessions. Hence, instruction appeared to
result in rapid acquisition of behavioral chains, but poor maintenance of behavior across time. Contingency shaped responding, on the other hand, was characterized by more errors to acquisition of the chain, but also by relatively enhanced maintenance of the behavior.

The purpose of Experiment I, therefore, was to examine the effects of introducing vocal instructional stimuli on the acquisition and maintenance of the four-component chain of responses.

The rationale for investigating the effects of vocal instructional stimuli were two-fold: (1) a great deal of human instruction is verbal, in this instance auditory, in nature; and (2) vocal, as opposed to visual, instructional stimuli required the subjects in this procedure to respond more exclusively to the vocally designated correct chip in each group, which may enhance maintenance of correct responding while also providing the benefit of rapid acquisition of the correct behavior.

Experiment I consisted of five blocks of sessions. Each block was composed of four sessions conducted across two days. Following Peterson's (1980) nomenclature, the morning session of the first day was designated a Control Learning (CL) session. The afternoon session of the first day was designated as a Control Relearning (CRL) session. On the second day of a block, the morning session was designated an Instructional Learning (IL) session, while the second session of the pair was an Instructional Relearning (IRL) session.

Each acquisition session, CL or IL, began with a new sequence of correct chips. The CRL and IRL sessions were conducted with the same correct chip sequences as were used in the morning acquisition.
sessions. In CL sessions, the session started with the experimenter placing the discriminative stimulus bar over the first group of chips. If the subject touched the designated correct chip upon instruction, the wooden bar was moved to the next group of chips. If an incorrect chip was touched, the experimenter covered the array of chips with a screen (TO) for five seconds and reset the counter to zero. The screen was then removed and the trial resumed with the same group of chips. This sequence was repeated until the child touched the correct chip, at which time the wooden bar was moved to the next group of chips. One point was earned on the counter for each sequence completed without error. Sessions ended when the sequence of correct chip responses was emitted on five successive trials without error. In the CRL session later the same day, the subjects were exposed to the same experimental conditions that existed in the morning CL session, including the same correct chip sequence.

During the morning IL session, the procedure was identical to a CL session except for the introduction of vocal instructional stimuli for correct responding. Those stimuli constituted the independent variable in Experiment I. In IL sessions, each trial was conducted in the following manner: The experimenter placed the discriminative stimulus bar over the first group of chips. The experimenter then said to the subject, "Touch the (color) chip." The chip designated by the experimenter was the correct chip in that group. If the subject responded correctly, the bar was moved to the next group of chips, as in CL sessions. An error resulted in the TO sequence described above.
The afternoon IRL session was identical to the morning CL session. In other words, the sequence of correct chips was the same as that in the earlier IL session, but without the vocal instructions. All subjects participated in Experiment I.

Experiment II: Effects of Limited Vocal Instruction

The purpose of Experiment II was to examine the effects of a limited set of vocal instructions on the acquisition and maintenance of behavior chains. Smiley (1974) investigated the effects of limited verbal instructions on acquisition of behavioral chains and found that such instructions were effective in generating more rapid acquisition and maintenance. More specifically, she told children in her study that she would tell them the correct response sequence only once. The question of interest in Experiment II was: What are the effects of similar instructions on the acquisition and maintenance of correct responding in the present procedure?

Experiment II was conducted as Experiment I, with the exception of the IL sessions. On the first trial of the IL sessions, the experimenter placed the bar over the first group of chips and provided a limited set of vocal instructions by stating, "Listen carefully to what I say. I will tell you the correct chip to touch only once. Then you will have to remember by yourself." The experimenter then provided instructions as in Experiment I as to which chip to touch (by color). Beginning with the second trial of the session, the procedure for the remaining IL sessions was conducted as in CL sessions. The experiment consisted of five blocks of paired sessions.
Two subjects participated in Experiment II.

**Experiment III: Effects of the Sequence of Sessions**

The purpose of Experiment III was to determine the possible effects the order of the CL, CRL, IL, and IRL sessions had on acquisition during the IRL session. In Experiment I, the subjects were exposed to the same stimulus conditions and response requirements in the CL and CRL sessions. While the conditions of the IL sessions differed, the stimulus conditions present at the beginning of the IRL sessions were identical to those encountered during the previous day's CL/CRL sessions, with the exception of the sequence itself. Given that arrangement, the subjects could be expected, on the basis of their immediate past history of reinforcement, to respond during IRL sessions as they had during the previous CL/CRL sessions since the IRL sessions shared the same stimulus characteristics. Such a tendency would function to inflate the number of errors during IRL and, thus, suggest that instruction had been relatively ineffective. Experiment III was an attempt to control for that possibility by conducting the CL/CRL sessions consecutively followed by consecutive IL/IRL sessions and vice versa.

The total number of each type of session as well as the format of the sessions was the same as in Experiment I. Three subjects participated in the experiment. Two of the subjects were presented with consecutive CL/CRL sessions followed by an equal number of IL/IRL sessions while the third subject was exposed to the reverse order. As in Experiment I, two sessions, CL/CRL or IL/IRL, were conducted each day.
RESULTS

Experiment I

Experiment I was an investigation of the effects of introducing vocal instructional stimuli on the acquisition and maintenance of the four-link chains. Summary data for each of the subjects in the three experiments are presented in Figure 1. The medians presented were computed from the five sessions in each condition, either CL, CRL, IL, or IRL sessions.

All of the subjects made more errors during the CL sessions than in the CRL sessions with the same response sequences. There were, however, differences among the subjects in terms of the median number of errors between CL and CRL. With the exception of Subject 1, the number of errors during CRL was at least half the number made during the CL sessions.

When the vocal instructional stimuli were presented during the IL sessions, the subjects made virtually no errors before acquiring the chains to criterion. Each of the subjects appears to have followed the instructional stimuli with the result of rapid and near error-free acquisition of the chains. When presented with the same sequences during the IRL sessions, errors occurred before the chains were acquired. Only in the case of Subject 2 did there appear to be transfer of stimulus control of responding from the vocal instructional stimuli in the IL sessions to the response sequences in the IRL sessions. Subjects 3, 4, and 5 made more errors during IRL
Figure 1. Median Errors for Control Learning, Control Relearning, Instruction Learning, and Instruction Relearning Sessions for Each Subject in Experiments I, II, and III.
than in CRL. Four of the subjects, S1, S2, S4, and S5, however, made fewer errors during the IRL sessions than in the CL sessions. On the basis of this comparison, it appears that those subjects benefitted to some degree by the presence of instructional stimuli in the IL sessions. Subject 3 was the only exception in this regard.

Individual session data for each subject in Experiment I are presented in Figure 2. The data points reflect the actual number of errors made in each session before the chains were acquired to criterion. Session by session comparisons are made by comparing a CL data point for a given session with the data point for the paired session in CRL and likewise for the IL and IRL sessions. For example, Subject 1 made 80 errors before acquiring the sequence in session 1 of CL. When exposed to the same sequence in the CRL session later that day, he made 79 errors before acquiring the sequence.

As can be seen in Figure 2, there was considerable variability in the number of errors per session for Subjects 1 and 4, particularly in the CL and IRL sessions. The error pattern for Subjects 2, 3, and 5, on the other hand, shows a tendency towards progressively fewer errors during the CL and CRL sessions. Such a trend is indicative of the "learning to learn" phenomenon described by Harlow (1949). An analysis of the distribution of errors across the links of the chains did not reveal a consistent pattern among the subjects. Subjects 1, 3, and 4 were exposed to the shaping procedure described earlier. While the behavior of Subjects 1 and 4 was characterized by more variability, in terms of errors across the CL and CRL sessions, the
Figure 2. Number of Errors per Session for Control Learning, Control Relearning, Instruction Learning, and Instruction Relearning Sessions for Each Subject in Experiment I.
performance of Subject 3 was among the least variable of all five subjects. The findings of Experiment I, then, were inconclusive with regard to possible differential effects of shaped vs. directed acquisition during initial training and subsequent performance.

In summary, the results of Experiment I showed that providing vocal instructional stimuli resulted in near errorless acquisition of the four-link chains. Reacquisition of the same sequences was enhanced, compared to acquisition without instruction (CL), in four of the five subjects. In three of the five subjects, however, reacquisition of the sequences following instruction was no better than reacquisition following no instruction. Thus, chains of behavior acquired through contingency shaping, as in the CL sessions, were maintained better over time (CRL), than chains acquired rapidly and with few errors with the aid of instruction (IL). Said another way, the instructional stimuli did not significantly benefit the subjects in terms of later reacquisition of the same response sequences compared to acquisition and reacquisition without instruction. The findings of the experiment are in agreement with those reported by Boren and Devine (1968), Peterson (1980), Ozuzu (1982), and Danforth (1983) in terms of the effects of providing instructional stimuli on the acquisition and reacquisition of response sequences. Those studies employed visual instructional stimuli. The findings of Experiment I extend the generality of those results to vocal instructional stimuli as well.
Experiment II

The purpose of Experiment II was to examine the effects of a limited set of vocal instructions on the acquisition and maintenance of the response sequences. As in the Smiley (1974) study, in which a group design was used, the children in Experiment II were told to remember the correct response sequence as it would be given to them only once.

Subjects 1 and 2 participated in Experiment II. Summary data, in terms of median number of errors, are presented in Figure 1. In contrast to his performance in Experiment I, Subject 1 made as many errors during the CRL sessions as he did during the CL sessions. Subject 2 performed in a manner similar to that observed in Experiment I in that CRL errors were considerably less frequent than CL errors. While the median number of CRL errors was about the same as that observed in Experiment I, the number of CL errors was about half that observed in Experiment I.

When provided with the limited set of vocal instructions, Subject 1 still made errors during the IL sessions. Limited instruction for this subject resulted in four times as many errors during IL as occurred with instruction in Experiment I. The limited set of vocal instructional stimuli did not benefit this subject in terms of reacquisition of the sequences during IRL sessions. In fact, more errors occurred during IRL than either the CL or CRL sessions. It appears that the limited set of vocal instructions actually enhanced the number of errors during IRL for this subject, compared to
reaquisition following the CL sessions.

For Subject 2, the effects of providing a limited set of vocal instructions was the same as that observed with instruction on each IL trial in Experiment I. The limited set of vocal instructions resulted in errorless acquisition of the response sequences as well as near-errorless reacquisition of the sequences later in the day. Compared to his CL/CRL performances, the limited set of instructions were effective in producing rapid, error-free acquisition as well as benefitting the subject in later reacquisition of the sequences with the advantage of fewer learning trials.

Individual session data for the two subjects are presented in Figure 3. As in Figure 2, the data points reflect the actual number of errors in each session. A session-by-session comparison of the number of errors to acquisition in the paired CL/CRL sessions reveals that Subject 1 made more errors in three CRL sessions than he made in the three earlier paired CL sessions. It appears that this subject's behavior did not come under the control of the response sequences in the CL sessions. The behavior of Subject 2 was relatively much less variable across sessions than that of Subject 1. Subject 2 continued the trend observed in Figure 1 of learning the chains more efficiently across differing response sequences.

The behavior of Subject 2 replicated, within an individual organism experimental methodology, the results of Smiley's (1974) study regarding the effects of providing a limited set of vocal instructions on acquisition and maintenance of behavioral chains. The behavior of Subject 1, however, does not support her findings. Taken alone, the
Figure 3. Number of Errors per Session for Control Learning, Control Relearning, Instruction Learning, and Instruction Relearning Sessions for Subjects 1 and 2 in Experiment II
performance of Subject 1 would suggest that such limited instruction actually retards later reacquisition when compared to reacquisition following no instruction at all.

Experiment III

The purpose of Experiment III was to determine the possible effects the order of the CL, CRL, IL, and IRL sessions had on errors to acquisition during IRL sessions. In Experiment I, the subjects were exposed to the same stimulus conditions and response requirements in the paired CL and CRL sessions. While the conditions of the IL sessions differed, the stimulus conditions present at the beginning of the IRL sessions were identical to those encountered during the previous day's CL/CRL sessions, with the exception of the sequence itself. Given that arrangement, the subjects could be expected, on the basis of their immediate past history of reinforcement, to respond during IRL sessions as they had during the previous CL/CRL sessions since the IRL sessions shared the same stimulus characteristics. Such a tendency would function to inflate the number of errors during IRL and, thus, suggest that instruction had been relatively ineffective. Experiment III was an attempt to control for that possibility.

Subjects 3, 4, and 5 participated in Experiment III. Subjects 4 and 5 were exposed to five consecutive CL/CRL blocks followed by five consecutive IL/IRL blocks, while Subject 3 was exposed to the five consecutive IL/IRL blocks first followed by the five CL/CRL blocks. Summary data, in terms of median number of errors for each
type of session, are presented in Figure 1. While the median number of errors was different in some cases, the general findings of Experiment I were replicated for each subject in Experiment III. As in Experiment I, each subject in Experiment III made more errors to criterion in the CL sessions than in the CRL sessions. Compared to Experiment I, each of the subjects also made fewer errors during the CL sessions of Experiment III. Subject 4 showed the most change in this regard; the median error level in the CL sessions of Experiment I was 33 compared to 10 in CL sessions of Experiment III. Subject 4 also showed considerable improvement in the number of CRL errors during Experiment III compared to the level of CRL errors in Experiment I. For Subjects 3 and 5, the CRL medians were about the same in both experiments.

The performance of each subject during the IL sessions of Experiment III was the same as that observed during the IL sessions of Experiment I. When subjects were told which chip to touch, no errors occurred before the sequences were acquired to criterion, with the exception of Subject 3 who made 1 error during the first IL session of Experiment III. As with CL errors, each subject in Experiment III also made fewer errors during the IRL sessions than occurred during the same type of sessions in Experiment I. The median number of errors during IRL in Experiments I and III were about the same for Subjects 4 and 5. Subject 3, on the other hand, made about half the IRL errors in Experiment III as he did during IRL in Experiment I.

For each subject in Experiment III, reacquisition of the sequences in CRL was better, in terms of median error level, than reacquisition
in the IRL sessions following instructed acquisition. When reacquisition following instruction was compared to acquisition without instruction (CL), however, Subjects 4 and 5 made fewer IRL errors than CL errors in Experiment III. Subject 3, in contrast, made more IRL errors than CL errors. In terms of these comparisons, the data of each subject in Experiment III replicates the individual findings in Experiment I.

Individual session data for each of the subjects in Experiment III are presented in Figure 4. The data points reflect the actual number of errors per session. By noting the difference in the scales, a comparison of each subjects' performance in Figure 2 and Figure 4 shows the degree to which performance improved between Experiment I and Experiment III, particularly for Subject 4. Otherwise, the patterns observed are similar in each figure. Across session variability in the number of errors was greater in the CL and IRL sessions than in the IL and IRL sessions. In that sense, session-by-session variability in the IRL sessions more closely resembled that observed in CL sessions, which suggested that the subjects were reacting to the sequences in IRL as if they were being encountered for the first time, as they were, in fact, during the CL sessions.

Experiment III was an attempt to determine if the sequence in which the CL, CRL, IL, and IRL sessions were conducted in Experiment I contributed to the number of errors during the IRL sessions. It was thought that more errors might occur during the initial links of the IRL trials since the stimulus conditions were the same as those
Figure 4. Number of Errors per Session for Control Learning, Control Relearning, Instruction Learning, and Instruction Relearning Sessions for Subjects 3, 4, and 5 in Experiment III.
encountered during CL and CRL sessions. Consequently, the distribution of errors across the links of the chains was determined for each subject in Experiment I and III in order to determine if systematic changes occurred in the distributions as a function of the change in the order in which the sessions were sequenced. Figure 5 presents the error distributions in Experiments I and III for Subject 3. The number of actual errors for the CL, CRL, IL, and IRL sessions are plotted as a function of the links in the four-response sequences. The number of errors for each link within each type of session was determined by counting each error that occurred on a given link in each session and summing those totals across the five sessions of each type in each experiment.

An inspection of Figure 5 shows that the distribution of IRL errors across the links of the chains changed considerably from Experiment I to Experiment III. Most of the change occurred along the final three links of the chain. The number of errors on the first link showed the least change of all. The latter fact is surprising, especially if one assumes that errors on the first link would be most affected by the possible sequence effects discussed earlier.

The error distributions for Subjects 4 and 5 also changed from Experiment I to Experiment III. In terms of patterns, each subject differed and consistencies among the subjects were not apparent, except in the generally lower levels of error observed in Experiment III and in the observation that errors on the first link were no more sensitive to the sequence effects than errors on the other links of the chains.
Figure 5. Number of Errors as a Function of Links of the Chains for Control Learning, Control Relearning, Instruction Learning, and Instruction Relearning Sessions for Subject 3 in Experiments I and III.
Overall, the findings of Experiment III replicated those of Experiment I. Each subject in Experiment III performed as s/he did in Experiment I, with the exception of each making fewer errors in Experiment III. Sequence efforts did not appear to have a major role in the findings of Experiment I in terms of the relative differences between and among errors in the CL, CR, IL, and IRL sessions. While changing the sequence in which the sessions were conducted did result in changes in the distribution of IRL errors across the links of the chains, the changes were not systematic across the links or the subjects. It remains possible, however, that the sequence effects were obscured by the trend towards fewer errors overall.
DISCUSSION

The results of Experiments I and III demonstrated that children can acquire chains of behavior quickly and with few errors when provided with discriminative stimuli for correct responding. In Experiments I and III, vocal instructions functioned as the discriminative stimuli (S\(^D\)). Even though the instructions were clearly effective in evoking rapid and near error-free acquisition of the response sequences, instruction, as it was studied here, was not substantially more effective than non-instruction in terms of maintenance of the acquired behavior across time. In terms of later reacquisition of the sequences, reacquisition was better when the sequences were acquired without instruction than with it. The findings obtained in Experiments I and III replicated those reported by Boren and Devine (1968) with monkeys, and Peterson (1980), Ozuzu (1982), and Danforth (1983) with children. The present results extend the generality of these findings to a repeated-acquisition procedure in which the instructional stimuli were vocal in nature and where the visual aspects of the learning situation remained the same when instruction was provided as well as in the absence of instruction.

Vocal instructions were used in an attempt to control for possible effects of altering the stimulus array but also as an effort to assure that the children would attend more closely to the plastic chips and, possibly, the correct chip sequences. While the subjects clearly came into contact with the vocal S\(^D\), they apparently did not
come under the influence of the sequences. If they had, fewer errors
than occurred would have been emitted during the IRL sessions. The
curves in the CL and IRL quadrants of Figures 2, 3, and 4 were quite
similar. The data in CL quadrants reflects errors to acquisition
without instruction for new sequences. A comparison of the curves in
the IRL quadrants suggests that the subjects were reacting as if they
were encountering the sequences for the first time, even though they
were being presented with them for the second time that day. It
appears, then, that the effects of instruction were not as enduring
as the strengthening of behavior which occurred during contingency
shaping in the CL sessions.

The generality of the effects of instruction on acquisition and
maintenance of the response sequences did not appear to depend on
the sequence in which the sessions were conducted across time. Even
though the results of Experiment III were more difficult to compare
to those of Experiment I, due to the lower levels of error, the main
effects were very similar in both experiments. While sequence effects
cannot be ruled out on the basis of the findings of Experiment III,
such effects probably cannot account for the majority of the errors
in the IRL sessions of Experiment I. An improved experiment to con­
trol for sequence effects would be one in which the subjects had no
previous history, as they did in Experiment I. In addition, some
evidence for sequence effects might be obtained in an experiment in
which one attempted to demonstrate that such effects do occur. For
example, Experiments I and III could be replicated with the exception
that the first chip in each sequence remain the same across all CL and
CRL sessions. Such an arrangement would serve to strengthen that response more relative to the other responses in the chains and make it even more likely that errors would occur on the first link of the IRL sessions. It seems that one could expect the errors to occur at the same location during IRL as was reinforced repeatedly during CL and CRL. If such a pattern were forthcoming, then the sequence of sessions could be altered, as in Experiment III, and the sequence effects possibly observed better, if at all. Another caution would be for the baseline to be carried out long enough so that learning-to-learn was no longer evident. The subjects in the present study, with the possible exceptions of S2 and S3, appeared to be acquiring the chains with greater efficiency as the study progressed.

In addition to sequence effects, other factors may have contributed to the findings of Experiments I and III. The studies by Boren and Devine (1968), Thompson (1970, 1971), and Hursh (1977) demonstrated the importance of presenting a salient TO following incorrect responses, or $S^P$ following correct responses in the Hursh study, on the acquisition of response sequences. In the present study, TO followed errors in each type of session. During CL sessions, TO presumably weakened the response it followed. Instruction, during the IL sessions, did not often result in errors and, consequently, little weakening of incorrect responses. It might be that contingency shaping is more effective, in the long run, CRL in the present case, because it weakens as well as strengthens behavior. Instruction learning, on the other hand, provided little occasion for
weakening of incorrect responses by the TO procedure. The instructions employed in the present study did not specify what was incorrect or, for that matter, imply a positive consequence.

The results of the second experiment were inconsistent across the two subjects and, therefore, only partially replicated the results of Smiley's (1974) study. For Subject 2, the limited set of instructions functioned to engender rapid acquisition with few errors as well as maintenance of the acquired chains. When the performance of Subject 2 was compared across Experiments I and II, the type of instruction appeared to make no difference in acquisition or reacquisition of the chains. For Subject 1, limited instructions appeared to be worse than no instruction in terms of errors to reacquisition. The behavior of this subject was quite variable across all sessions in the study. Informally, he was cooperative in coming to the experimental sessions but, often, he seemed to respond almost randomly or would make the same errors repeatedly.

In summary, the repeated acquisition procedure developed by Boren and Devine (1968) appears to be applicable for use with human subjects. The baselines of acquisition and reacquisition of behavioral chains appear to be sensitive to variables that have been shown to have effects on nonhuman performance. In the present study, humans performed in a manner similar to that observed with nonhumans (Boren & Devine, 1968), and, in doing so, did not follow the pattern in human-nonhuman differences described by Lowe (1978). It should be recalled that many of the discrepancies noted between human and nonhuman performance on basic schedules of reinforcement have involved
adult human subjects. Another point in this regard concerns data reported by Peterson (1980) concerning adults who participated in her study. She reported that adults appeared to benefit from instructions in that they made few errors before reacquiring the response sequences during IRL sessions. She speculated that the differences between the children and adults may lie in the extensive verbal repertoire of adults. The findings of the present study would appear to add weight to the plausibility of that speculation. It would seem valuable, then, to conduct further studies with children in which laboratory established procedures and baselines are the focus of inquiry. While many such studies might appear to be simple replications of established findings with humans, there does not appear to be a substitute, short of speculation, for establishing the generalities of principles of behavior across species.
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