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DIFFERENTIAL RESPONSE LATENCIES USING AUDITORY STIMULI

by

Albert Edward Neal

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
April 1987

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Albert Edward Neal

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DIFFERENTIAL RESPONSE LATENCIES USING AUDITORY STIMULI

Albert Edward Neal, Ph.D.

Western Michigan University, 1987

Previous research has identified and isolated the elicited (autoshaped) control of pigeons' response latencies. The present research, using auditory frequencies as discriminative stimuli, was designed to eliminate the intrusion of this elicited control.

Two experiments are presented, both using a discrete-trial, two-component multiple schedule. In Experiment 1, in which a two-key arrangement was used, pigeons were required to peck a continuously-illuminated left key when one of two different frequencies, each correlated with a different amount of reinforcement, was presented behind the illuminated right key. In Experiment 2, in which a three-key arrangement was used, pigeons were required to peck either a left or right continuously illuminated key, when one of two different frequencies, each correlated with a different amount of reinforcement, was presented behind an unlit center key.

Experiment 1 failed to produce a separation in median response latencies; one could not determine whether this represented failure of the pigeon's response to come under the control of the different auditory frequencies or

failure to come under the control of the different reinforcement variables.

Experiment 2 demonstrated that the responses could be brought under the control of the two auditory frequencies, that the median response latencies could be affected by different amounts of reinforcement, and most importantly, all responses were under the control of discriminative, rather than elicited, stimuli.

EXPERIMENT 1

Introduction

Considerable research with pigeons has demonstrated that one can use visual stimuli (hues) associated with different reinforcement variables to evoke differences in response-latencies (Hesse, 1984; Hesse, Michael, Whitley, Nuzzo, & Sundberg, 1984; Neal, 1985; Nuzzo, 1981; Schlinger, 1984; Winters, 1987). If pigeons are required to perform on a multiple schedule in which various reinforcement variables are programmed for responses to a key illuminated with different hues, they will peck the key with latencies that reflect the difference in the amount of reinforcement, number of responses to reinforcement, or the probability of reinforcement. The hue that is associated with more reinforcement, fewer responses to reinforcement, or higher probability of reinforcement, will come to control shorter response-latencies than the hue associated with less reinforcement, more responses to reinforcement, or a lower probability of reinforcement.

In the research cited above, attempts have been made to demonstrate differential control of response latencies to discriminative stimuli through the arrangement of various reinforcement variables. Control of the response latencies from other sources would obscure the effect.

One such source of control that has been observed in much of the research in which responses are evoked by visual stimuli has been attributed to an elicited relationship between the stimulus presentation and the response to that stimulus. Brown and Jenkins (1968) first demonstrated this elicited control in an experiment in which, through a classical conditioning procedure, they taught naive magazine trained pigeons to peck a lighted key. If one conducts several trials in which a lighted stimulus is presented behind the key of a pigeon chamber for a short period of time (8s) and then follows this presentation with the operation of the lighted food hopper for 4s, pigeons that were food deprived and magazine trained to eat from the hopper would begin to peck the lighted response key. Although the issue has not been resolved, there is a strong suggestion that responses obtained in this fashion are not under the operant stimulus control of the lighted key, but rather are under elicited control (Gamzu & Williams, 1973; Schwartz & Gamzu, 1977). In the latency research cited previously, the critical dependent variable is the time from the onset of the stimulus to the first response; if this response is elicited rather than under operant stimulus control it makes the outcome of such research more difficult to interpret. For instance, if the response is elicited it may not be as amenable to control by reinforcement variables, and, second, there is

some indication that the latency of the first peck is shorter than one would expect, had the control been operant. Therefore, the autoshaped relation between key pecks and visual stimuli may intrude into experiments in which the response is thought to be solely under operant control. More understanding of the difference between these relationships is necessary in order to react properly to past and future research.

If one were able to eliminate the interference of autoshaped key pecks, it would then permit one to study purely operant response latencies. Experiment 1 is an attempt to eliminate autoshaped responses by employing stimuli to which responses are demonstrably more difficult to autoshape, auditory stimuli. Steinhauer, Davol, & Lee, (1977) in describing the procedure for autoshaping the pigeon's key peck to an auditory stimulus observe, "Pilot work...indicated that birds given 10 magazine-training trials autoshape slowly, if at all, whereas autoshaping to a lighted key readily follows 10 magazine-training trials." (p. 97) And further, Steinhauer (1982), in describing research in which the similarity between the key stimulus tone and the hopper stimulus tone is investigated comments, "One of the striking features of these data is the substantially lower rates of responding than are obtained using lighted grain hoppers and lighted keys." (p. 285)

Therefore, if this research is successful, autoshaped responses will not occur; the response latencies produced will be solely under the control of the operant stimulus.

Method

Subjects

Two male White Carneaux pigeons (Birds #5670 and #6771), and two female Crown King pigeons (Birds #6493 and #11948) were used as subjects. They were maintained at approximately 80% of their free-feeding weight for the duration of the experiment.

Apparatus

The birds were trained in a standard three-key test chamber (Lehigh Valley Electronics) with modified lighted cells behind each key. Only the right and center key were used; the left key was covered with a metal plate. The test chamber was housed in a sound- and light-attenuating Accoustical Environment (Industrial Accoustic Co., Model #102311); additional auditory isolation was achieved by the masking sound of the exhaust fan. During the early phases of the research, the light mounted in the ceiling of the outer accoustical environment served as the house-light. This light contributed to the general illumination of the pigeon's chamber, however, the response panel was

shadowed by the chamber ceiling. Consequently, another houselight (4-watt bulb) was mounted on the outside of the transparent acrylic door of the chamber. A 1-inch speaker, mounted behind the lighted-perforated right key, provided the subjects with a 90db auditory stimulus (measured 1.0 cm from the surface of the key).¹ The perforations in the key allowed sound to enter the chamber from behind the key. Sound was largely prevented from entering the chamber through the gap around the center key or through the food hopper opening by enclosing the rear of the right key (with light and speaker) in a sound-attenuating styrofoam box. Sound pressure readings made 1.0 cm from the surface of the two keys showed a 10 decibel difference. The programming of events and recording of data were performed by a Commodore 64 computer which was connected to the chamber with a computer interface (Psychronix Co., Commodore Interface, Model #35) and standard electromechanical equipment. Data, latencies of responses made to the center key were displayed on a terminal screen, stored on diskettes, and later transferred to a large main-frame computer for analysis (medians computed) and the printing of frequency distributions. Reproduction of the computer program for the control of the experiment appears in Appendix A.

Procedure

Preliminary Training

The birds were hand-shaped to peck an illuminated white center key. During a general experimental training phase, each bird was required to complete successively higher fixed-ratios until a consistent fixed-ratio performance on an FR 25 was reached. All birds were then placed on a two-component multiple schedule in which one of two tones (512 Hz or 1024 Hz) was presented behind the right key with a probability of 0.5; both the center and right keys were illuminated with white light continuously during the experiment. Once the tone sounded, a single peck on the center key would turn off the tone, illuminate the hopper opening, and raise the food hopper for 4s, after which an intertrial (ITI) of a variable 5s (3, 5, or 7s) was imposed. Should the pigeon peck during the ITI, an additional variable interval of non-responding was required. Should the pigeon not peck or not complete the ratio requirement during 30s of tone presentation, a new ITI was imposed and another trial began. The FR component was increased to an FR 15 in both stimulus conditions once stable median response latencies were produced.

Baseline

Once stable responding was achieved at the FR 15, all birds were placed on an FR 3 for 3s access to grain in the presence of both auditory stimuli. Training continued until a visual inspection of the graphed median latencies on two-cycle semi-log paper for each stimulus condition showed no systematic changes across sessions. In addition, frequency distributions of latencies were inspected; a reduced range of latencies was also used, to a lesser degree, as an indicator of stability.

Experimental Phase

For each bird, after baseline data were collected, the tone associated with the shorter median latencies was chosen to be the stimulus correlated with the less favorable independent variable parameter. A summary of the experimental conditions for all subjects is presented in Table 1.

Pigeons were again placed on a two-component multiple schedule in which the center key, the contingency key, and the right key, the stimulus key, were illuminated with white light throughout the session. After the variable intertrial interval, a low- or high-frequency tone was presented from behind the right key. During Experimental Phase 1, an FR 10 for 2s access to grain was required for

responses during the low tone, while only an FR 3 for 6s of grain was required for responses during the high tone.

Table 1
Experimental Procedure For All Subjects

<u>Condition</u>	<u>Independent Variables</u>	
	Low Tone Ratio/Amt.S+	High Tone Ratio/Amt.S+
Baseline	FR 3/3s	FR 3/3s
Experimental Phase 1	FR 10/3s	FR 3/6s
Experimental Phase 2	FR 15/2s	FR 3/6s
Experimental Phase 3	FR 30/2s	FR 3/6s
Experimental Phase 4*	FR 30/2s	FR 3/6s

* Tones changed from 512 Hz/1024 Hz to 348 Hz/640 Hz.

During Experimental Phases 2 and 3, the ratio requirement during Tone 1 was increased to FR 15 and FR 30, respectively. During Experimental Phase 4, the reinforcement variables were not changed, however, the frequency of the low tone was changed to 348 Hz and the high tone to 640 Hz. It should be noted that most previous research manipulated only one reinforcement variable at a time. The two variables were manipulated simultaneously in order to produce the most dramatic effect. In spite of increasingly different reinforcement variables, the data for the four subjects in this preliminary research showed no sep-

aration in median latencies in the predicted direction when the reinforcement conditions were associated with different auditory frequencies. Failing to obtain a separation in median latencies for the most extreme difference in reinforcement conditions (FR 30 for 2 seconds access to grain, versus FR 3 for 6 seconds access to grain), it was thought that the two frequencies (512 and 1024 Hz), being an octave apart, might be too difficult a discrimination.

Results

For the graphed data of this experiment, see Figures 1, 2, 3, & 4. Figures follow as numbered.

There are no data to indicate that pigeons find octave discriminations more difficult, but given that the higher frequency (1024 Hz) would contain, as a fundamental frequency, the second partial frequency (512 Hz) of the lower note's fundamental frequency (512 Hz) it was thought that that might be the source of difficulty. Therefore, two new frequencies (348 and 640 Hz) were chosen, but produced similar results.

The two-key design was used in this experiment because it had been used by the author and others (Hesse, 1984; Schlinger, 1984) in previous research. It was not without its defect, however. When one obtained a separation between the median latencies, there was no

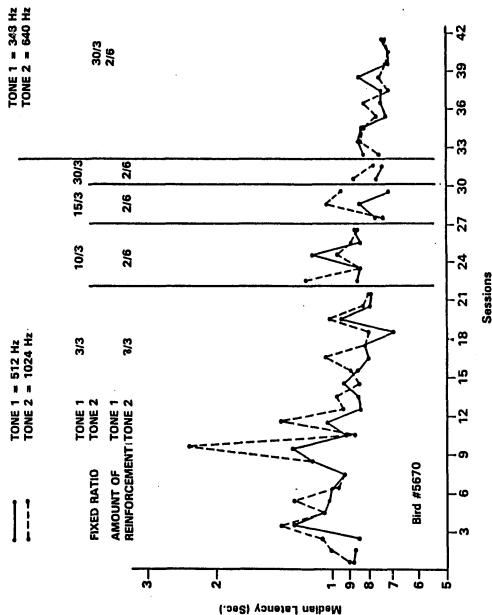


Figure 1. Experiment 1: Median Latencies for Bird #5670 Across Sessions.

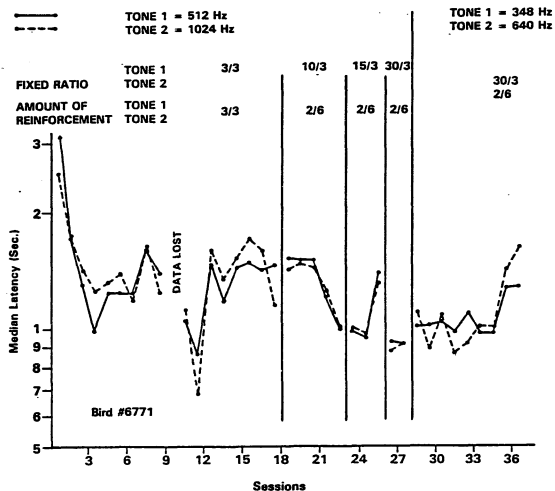


Figure 2. Experiment 1: Median Latencies for Bird #6771 Across Sessions.

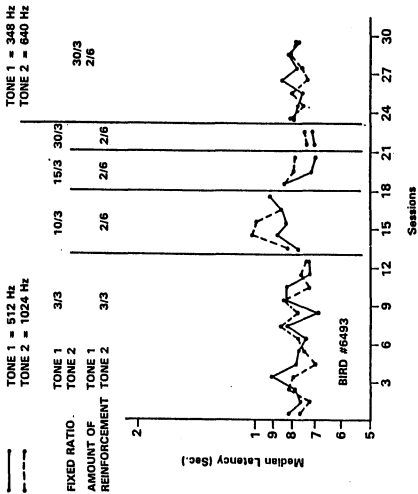


Figure 3. Experiment 1: Median Latencies for Bird #6493 Across Sessions.

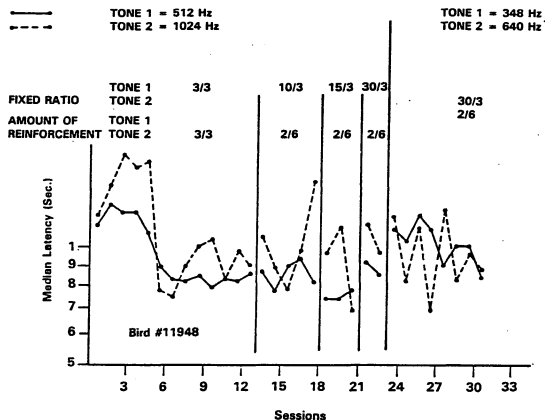


Figure 4. Experiment 1: Median Latencies for Bird #11948 Across Sessions.

problem, but, when there was not a separation, or when there were long periods in which the separation was slow to occur, one could not tell if the subjects were under operant stimulus control. The three-key arrangement of Experiment 2 was an improvement on this design.

EXPERIMENT 2

Introduction

The failure to produce differential latencies to the auditory stimuli in Experiment 1 is not a function of the pigeon's inability to respond differentially to disparate reinforcement variables; that has been well-established by the previously cited research using visual stimuli (Hesse, 1984; Hesse, Michael, Whitley, Nuzzo, & Sundberg, 1984; Neal, 1985; Nuzzo, 1981; Schlinger, 1984; Winters, 1987.) Nor is the pigeon's sensitivity to auditory stimuli in question. Stebbins (1970) reports that pigeons' hearing can be tested, although with some difficulty. Stebbins states, "we found the pigeon a recalcitrant subject, as others apparently have, for auditory experimentation" (p. 53). Experiments designed to test the auditory thresholds of the pigeon using standard operant chambers have been hampered by the pigeon's tendency to peck the key during the "quiet" periods. Better designed testing apparatus has eliminated most of these problems, and accurate auditory sensitivity data are now available. Auditory thresholds for birds range from below 200 Hz to a high of 8 kHz, with a peak sensitivity at 2 kHz. Although Stebbins includes pigeons' hearing in the data for birds, they as a species, differ in that they may respond to

frequencies as low as 0.5 Hz (Stebbins, 1983). The relevance of this information will be clear later because of the use of an extremely low frequency (69 Hz) in establishing stimulus control. In examining these data, one finds that the frequencies used in Experiment 1 (512 Hz/1024 Hz and 384 Hz/640 Hz) were well within the pigeon's range of auditory sensitivity. The avian auditory threshold function presented by Stebbins (1983) demonstrates that birds are able to respond to intensities as low as 10 db in the most sensitive portion of the auditory spectrum (2 kHz), 50 db at the lowest frequency tested (0.2 kHz) and 80 db at the highest (10 kHz). Even at the extreme ends of the sensitivity curve, the intensity of the stimuli used in this research (90 db) is well above the auditory threshold.

The ability of the pigeon to respond differentially to auditory frequencies has been demonstrated, as well. Evidence has been provided from tests of generalization to auditory stimuli (Jenkins & Harrison, 1960; Rudolph & Van Houten, 1977; Steinhauer, 1982). Jenkins & Harrison found that, when they performed generalization tests on pigeons, sharply peaked generalization gradients were produced if the subjects' responses were reinforced in the presence of a 1000 Hz tone that was alternated with the absence of tone in extinction. Rudolph & Van Houten compared the generalization gradients of pigeons trained to peck either

an illuminated key or an unlighted key in a dark chamber. They found that when the key was illuminated, the pigeons produced shallow generalization gradients to stimuli around the 1000 Hz training stimulus; pigeons that were trained to peck an unlighted key produced steeper generalization gradients. Although the research was designed to investigate how one stimulus "overshadows" another in stimulus control research, the data support the ability of the pigeon to respond differentially to different frequencies. Using a wide range of frequencies as evocative key stimuli, Steinhauer demonstrated that pigeons were more likely to autoshape to a key, behind which a 1000 Hz was sounded when the same 1000 Hz frequency was presented in the food hopper when reinforcement occurred, thereby pairing the key stimulus with the food hopper stimulus.

Given that the pigeon's auditory sensitivity curve encompasses the frequencies used and that the pigeon can discriminate among different auditory frequencies, and further, given that the pigeon is affected by the different reinforcement variables when controlled by visual stimuli, the question remains: Why is there no separation between median response latencies when the stimuli are auditory?

Using a single key response, one cannot tell whether the pigeons are failing to come under the control of the two different auditory frequencies, or failing to come

under the control of the disparate reinforcement variables, or both. The goal of the present research (Experiment 2) is to isolate the differential responding to different reinforcement contingencies from the differential responding to different auditory frequencies.

Michael (1986) suggested a three-key procedure that was being used by researchers at Western Michigan University (Winters, 1987) as a "topographical indicator" of whether or not the subjects are under the control of the discriminative stimuli. When the stimulus is presented behind the center key, the subjects are required to peck left in the presence of one stimulus and right in the presence of the other. Using such a procedure, one should be able to determine whether the subjects' responding can be brought under the control of different auditory frequencies, and then, investigate, separately, the effect of reinforcement variables on the latencies made to the auditory stimuli without the intrusion of elicited autoshaped responses.

Method

Subjects

One male White Carneaux (Bird #5670) pigeon and two female Crown King pigeons (#6493 and #11948), used in the previous research, and one naive male White Carneaux (#2683) pigeon were used as experimental subjects. They

were maintained at approximately 78% of their free-feeding weight for the duration of the experiment.

Apparatus

The birds were trained in a standard three-key test chamber (Lehigh Valley Electronics) with light-cells behind each key. The right and left keys, the contingency keys, were continuously illuminated, with the exception of time-out periods, with white light during each session. The center key, the stimulus key, was modified so that hues could be projected onto it, or tones could be produced through perforations in the key from a speaker mounted behind the intelligence panel and above the light-cell. The tones were produced by the Commodore 64 programming computer; sound pressure levels of 90 db taken 1.0 cm from the key surface were maintained for both auditory frequencies (69 Hz and 739 Hz) during most of the experiment. As a result of an error in the calibration of the sound-pressure meter (it registered 10 db lower than the calibration standard), and the suspicion that the intensity of the stimulus was operating more as a negative reinforcer than a discriminative stimulus, the sound pressure level was reduced during the latter part of the experiment to 60 db. A 4-watt houselight was mounted in the center of the chamber's ceiling. This light illuminated the test chamber's operandum panel and provided sufficient

light to illuminate the grain hopper opening. In order to inhibit the development of autoshaping to the stimulus key, the food hopper light was disconnected during Experiment 2. Research suggests that the less similarity between the key stimulus and the hopper stimulus, the more difficult it is to autoshape responses to the key stimulus (Steinhauer, 1982; Fisher & Catania, 1977). The food hopper contained a pellet reinforcer (Nutriblend Green, Purina Company) rather than the customary grain.²

The test chamber was housed in a sound- and light-attenuating Acoustical Environment (Industrial Acoustic Co., Model #102311); additional auditory isolation was achieved by the masking sound of the exhaust fan. Programming of events and recording of data were performed by the Commodore 64 computer which was connected to the chamber with a computer interface (Psychronix Co., Commodore Interface, Model #35) and standard electro-mechanical equipment. Data (latencies) were displayed on a terminal screen, stored on diskettes, and later transferred to a large main-frame computer for analysis (medians computed) and the printing of frequency distributions of correct responses to the two contingency keys. In order to determine whether autoshaped responses occurred, pecks on the center stimulus key were recorded, but they had no effect on the contingencies programmed on the other

two keys. Reproduction of the program for the control of the experiment appears in Appendix B.

Procedure

Preliminary Training

After magazine training in which the naive subject was trained to eat food from an illuminated food hopper, it was autoshaped to peck the left- and right-illuminated keys through the use of a variation of the autoshaping procedure developed by Brown and Jenkins (1968). An intertrial interval (ITI) of 90s (60s, 90s, or 120s with equal probability) began each trial; the right or left light was presented for 4s followed by 4s of illuminated food hopper. Pecks to the lighted key extinguished the light and raised the food hopper for 4s. Once the subject reliably pecked the illuminated keys, the light in the food hopper was disconnected; this was done to diminish the influence of the autoshaped training during the experiment.

Discrimination training with auditory stimuli began for the three other subjects. Birds #5670, #2683, & #11948 were placed on a two-component multiple schedule in which either a low-, or high-frequency tone was presented behind the non-illuminated center key, with a probability of 0.50. Pigeons generally resist pecking unlighted

keys.³ With the onset of the auditory stimulus, pecking the appropriate key was prompted by extinguishing the light behind the inappropriate key until the reinforcement period was over. In the presence of the low frequency tone behind the center key, the subjects were reinforced for pecking the right key; in the presence of the high frequency tone behind the center key, the subjects were reinforced for pecking the left key. Once the tone sounded, a single peck to the appropriate key would turn off the tone and raise the food hopper for 4s, after which an intertrial (ITI) of variable 5s (3, 5, or 7 seconds with equal probability) was imposed. Should the bird peck the center key or the inappropriate side key, the response was recorded, the stimulus terminated, and a time-out of 10s (later increased to 20s) began during which both side keys and the houselight were extinguished. Following the time out condition, the next ITI began. Should the pigeon not peck during 30s of tone presentation, a new ITI was imposed and another trial began; the latency for that trial was recorded as 30s for that stimulus condition. Once responding occurred regularly to both keys with a discrimination index of 0.90 or better, the prompt was delayed in gradual increments over successive sessions, according to a technique developed by Touchette (1971). The accuracy criterion for determining whether the birds were sufficiently under the control of the auditory stimuli to pro-

ceed with the experiment was a discrimination index which was computed by dividing the number of correct responses to the stimuli by the number of trials in which the stimuli were presented during each session. The delay value was increased in progressions of 0.5, 0.75, 1.00, 1.25, and 1.50 seconds, as long as the subject's discrimination index remained at or above 0.90. Once the median latencies for a particular subject became shorter than the value of the delayed prompt, and the discrimination index remained at or above 0.90, the prompt was removed, leaving both side lights illuminated for the entire trial (effectively, a delay of 30s, which was equal to the trial length). Visual inspection of the subjects confirmed that they were selecting the appropriate side key with alacrity. Should the pigeon peck during the ITI, an additional variable interval of non-responding was required.

Bird #6493 was added during the latter portion of the experiment. Rather than teach the discrimination using the delayed-prompt technique, a correction-trial procedure was used. The delayed-prompt technique required many sessions of gradually increasing the delay; therefore, because this bird was added late in the experiment the less arduous correction-trial procedure was employed. As with the three other subjects, Bird #6493 was placed on a two-component multiple schedule in which either a low-, or high-frequency tone was presented behind the non-illum-

inated center key, with a probability of 0.50. The procedure differed from that of the other subjects, however, in the following manner: Should the subject make an error, following the time out condition the next ITI began, and another presentation of the tone to which the error occurred was presented on subsequent trials until a correct response occurred (the correction procedure). After a correct response, the next presentation of the stimulus was again randomly generated by the computer.

Baseline

Baseline training continued for all subjects until a visual inspection of the graphed median latencies on two-cycle semi-log paper for each of the two auditory stimulus conditions showed no systematic changes across sessions. In addition, frequency distributions of latencies were inspected and a reduced range of latencies during each stimulus condition was also used as an indicator of stability. After baseline data were collected, the tone associated with the shorter median latency was chosen as the stimulus correlated with the less favorable independent variable parameter.

Experimental Phase

Bird #5670. The programming of experimental conditions for Bird #5670 is presented in Table 2.

Table 2
Experimental Conditions for Bird \$5670

Condition	Sessions	<u>Amount of Reinforcement</u>	
		High Tone	Low Tone
Baseline 1	1-23	4s	4s
Experimental Phase 1	24-28	6s	3s
Experimental Phase 2	29-34	6s	2s
Experimental Phase 3	35-40	6s	2s
Experimental Phase 4	41-45	6s	2s
Experimental Phase 5	46-55	6s	2s
Experimental Phase 6	56-66	2s	6s
Experimental Phase 7	67-78	2s	8s
Experimental Phase 8	79-84	1s	8s
Experimental Phase 9	85-89	2s	6s
Experimental Phase 10	90-94	1s	8s
Experimental Phase 11	95-116	2s	8s
		Green	Red
Baseline 2	117-120	4s	4s
Experimental Phase 12	121-132	2s	8s
Experimental Phase 13	133-14	8s	2s

Following the baseline training during which the parameters of the potential variables were the same in the presence of both stimulus conditions (i.e. 4s access to food), and beginning with Session 24 (Experimental Phase 1), the reinforcement conditions were altered to 3s access to food in the presence of the stimulus associated with the shorter median latencies (low tone, 69 Hz) and 6s access to food in the presence of the other frequency (high tone, 739 Hz). After 5 sessions the amount of reinforcement for responses to the low tone was reduced to 2s (Experimental Phase 2). During Sessions 35 through 45 (Experimental Phases 3 & 4), four stimuli were programmed to appear on the center key, green, red, high tone, or low tone, each with a probability of 0.25. The green hue and high tone stimuli set the occasion for pecking the left key; the red hue and low tone set the occasion for pecking the right key. Beginning with Session 46 and continuing through Session 55 (Experimental Phase 5), the green and red stimuli were omitted, but the presentation of the tone conditions continued.

A reversal of reinforcement conditions began with Session 56 (Experimental Phase 6); 6s access to food was made available for responses to the low tone and 2s access to food for responses to the high tone, followed by Sessions 67-78 (Experimental Phase 7) during which the access to food for responses to the low tone was increased to 8s,

Sessions 79-84 (Experimental Phase 8) during which access to food during the high tone condition was decreased to 1s, and Sessions 85-94 (Experimental Phase 9) during which access to food during the low tone was decreased to 6s and access to food during the high tone was increased to 2s. A return to the reinforcement conditions of Experimental Phase 8 in which the high tone was associated with 1s of reinforcement and the low tone, 8s occurred during Experimental Phase 10. Beginning with Session 95 (Experimental Phase 11) and continuing through Session 116, access to food for responses during the high tone was 2s and access to food for responses during the low tone was maintained at 8s. During Sessions 104 & 105 the intensity of the auditory stimuli was reduced to 70 db and then further reduced to 60 db for the rest of that part of the experiment that utilized tone.

Beginning with Session 117 and continuing until the end of the experiment only the hues, green and red, were programmed on the center key. Baseline data were obtained for responses to red (on the right key) and green (on the left key) when the access to food was 4s in each stimulus condition. From Session 121 through Session 132 (Experimental Phase 12), 2s access to food was obtained during the hue associated with the shorter median latencies (green) and 8s access to food during the hue associated with the longer median latencies (red). A reversal of

reinforcement conditions began with Session 133 (Experimental Phase 13) and continued until the end of the experiment.

Bird #11948. A summary of the programming of experimental conditions for Bird #11948 is presented in Table 3. Following the baseline training during which the

Table 3
Experimental Conditions for Bird #11948

Condition	Sessions	<u>Amount of Reinforcement</u>	
		High Tone	Low Tone
Baseline	1-9	4s	4s
Experimental Phase 1	10-12	3s	6s
Experimental Phase 2	13-21	2s	6s
Experimental Phase 3	22-27	2s	6s
Experimental Phase 4	28-32	1s	8s
Experimental Phase 5	33-79	2s	6s
Experimental Phase 6	80-103	2s	8s
Experimental Phase 7	104 -126	8s	2s

amount of reinforcement was 4s in the presence of both stimulus conditions, and beginning with Session 10 (Experimental Phase 1), the reinforcement conditions were altered to 3s access to food in the presence of the stimulus

associated with the shorter median latencies (high tone, 739 Hz) and 6s access to food in the presence of the other frequency (low tone, 69 Hz); during Sessions 13-21 (Experimental Phase 2), the amount of reinforcement during the high tone was reduced to 2s. During Experimental Phase 3, as with Subject #5670, four stimuli, green, red, high tone, or low tone were programmed to appear each with a probability of 0.25 on the center key. The green hue and high tone stimuli each set the occasion for pecking the left key; the red hue and low tone each set the occasion for pecking the right key. These visual stimuli were discontinued at Session 28 (Experimental Phase 4). Beginning with Sessions 28 and ending with 32 (Experimental Phase 5), the amount of reinforcement during the high tone was decreased to 1s and increased to 8s during the low tone. During Sessions 33-79 (Experimental Phase 5), the amount of reinforcement during the high tone was increased to 2s and decreased to 6s during the low tone. The amount of reinforcement variable was changed again between Sessions 80-103 (Experimental Phase 6); 2s during the high tone and 8s during the low tone. At Session 83, the intensity of the two auditory frequencies was reduced to 70 db, and at Session 85 it was further reduced to 60 db.

Beginning with Session 104 (Experimental Phase 7), the reinforcement variable was reversed across stimuli; now 2s during the low tone, 8s during the high tone.

Bird #2683. A summary of the programming of experimental conditions for Bird #2683 is presented in Table 4. Following the baseline training during which the amount of reinforcement was 4s access to food in the presence of both the high and low tones, and beginning with Session 10 (Experimental Phase 1), the reinforcement conditions were altered to 2s access to food in the presence of the stimulus associated with the shorter median latencies (high tone, 739 Hz) and 6s access to food in the presence of the low tone, 69 Hz. Beginning with Session 69

Table 4
Experimental conditions for Bird #2683

Condition	Sessions	<u>Amount of Reinforcement</u>	
		High Tone	Low Tone
Baseline	1-9	4s	4s
Experimental Phase 1	10-68	2s	6s
Experimental Phase 2	69-76	6s	2s
Experimental Phase 3	77-119	8s	2s

(Experimental Phase 2), the reinforcement variable was reversed across stimuli; 2s during the low tone, and 6s during the high tone. During Experimental Phase 3, the amount of reinforcement available for responses during the high tone was increased to 8s, but continued at 2s during

the low tone. At Session 80, the intensity of the two auditory frequencies was reduced to 70 db, and at Session 83 it was further reduced to 60 db.

Bird #6493. A summary of the programming of experimental conditions for Bird #6493 is presented in Table 5. Baseline training in which 4s access of food was available in the presence of both auditory frequencies was conducted during Sessions 1-30. During this baseline condition, beginning with Session 25, the intensity of the auditory stimuli was reduced to 70 db and reduced again at Session 27 to 60 db. During Experimental Phase 1 (Sessions 31-45), the amount of reinforcement obtained for responding on the left key during the high tone (739 Hz) was reduced to 2s; the amount of reinforcement obtained for responding on the right key during the low tone (69) was increased to 8s.

Beginning with Session 46 and continuing until Session 57 (Experimental Phase 2) red and green hues rather than tones were presented on the center key. Responding on the left key when the center key was green produced 2s access to food; responding on the right key when the center key was red produced 8s access to food. During Experimental Phase 3, beginning with Session 58, a reversal of the reinforcement conditions was programmed; now, key pecks in the presence of green produced 8s reinforce-

ment, and key pecks in the presence of red produced only 2s reinforcement.

Table 5
Experimental conditions for Bird #6493

Condition	Sessions	<u>Amount of Reinforcement</u>	
		High Tone	Low Tone
Baseline	1-30	4s	4s
Experimental Phase 1	31-45	2s	8s
		<u>Green</u>	<u>Red</u>
Experimental Phase 2	46-57	2s	8s
Experimental Phase 3	58-67	8s	2s

Data Collection

After the presentation of a stimulus, the latency of the correct first peck made to either of the side-keys was recorded. Incorrect responses to the side-keys and responses to the center key (always considered incorrect) were recorded per trial and totalled per stimulus condition. At the end of each session, all data were saved on diskette.

Data Analysis

Frequency distributions of response key latencies per stimulus condition were printed at the main-frame computer terminal. The print-outs also provided the median latency for responses to each stimulus condition as well as the total number of first responses made on the center key in the presence of each stimulus condition. Additionally, the main-frame program provided a trial-by-trial printout of each day's session indicating the stimulus presented, the latency of the correct response, and the trials on which there was an incorrect response. During the latter portion of this experiment, frequency distributions and median latencies were also obtainable from the Commodore 64.

Results

Bird #5670

As a result of the discrimination training program, the pigeon's responses came under the control of the appropriate stimuli with a discrimination index of 90% or more, with few exceptions. As a result of observations of the pigeon in the chamber it was determined that most errors during this baseline condition were the result of the bird starting a key-peck during the ITI and ending it

as the stimulus was presented; should the "ITI peck" occur to the wrong stimulus, an error was registered.

The data for Bird #5670 are presented in Figure 5. Stable median latencies across sessions were obtained during the last ten sessions of Baseline 1. The subject emitted shorter median latencies in the presence of the lower auditory frequency even though the reinforcement variable was the same for both tones; therefore, the amount of reinforcement was increased in the presence of the high frequency and reduced in the presence of the low frequency (see Figure 5). During Experimental Phase 1, in which the amount of reinforcement during the high tone was 6s access to food, and during the low tone 3s, no control by the reinforcement variable was observed. After the difference in the amount of reinforcement was changed to 2s during the low tone in Experimental Phase 2, control by the reinforcement variable was finally demonstrated; the median latencies became shorter in the presence of the high frequency (associated with 6s food) and longer in the presence of the low frequency (associated with 2s food). During Sessions 35-45, (Experimental Phases 3 & 4) four stimuli were programmed to appear separately on the center key (as with Bird #5670), each with a probability of 0.25. A high tone set the occasion for left key pecks, and the low tone, right key pecks, and, in addition, a green hue set the occasion for left key pecks and a red hue set the

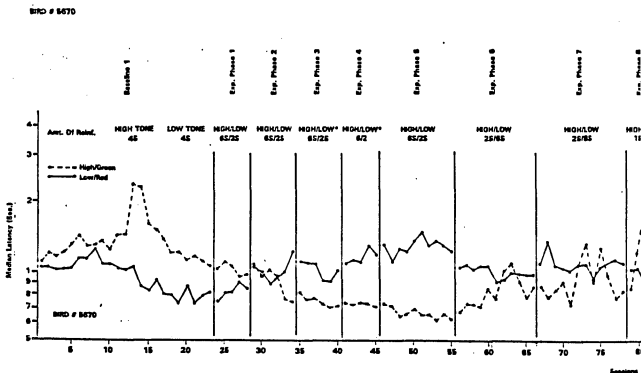
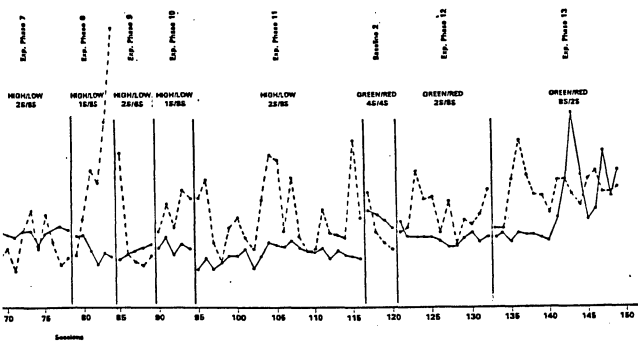


Figure 5. Experiment 2: Median Latencies for Bird #5670 Across Sessi



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occasion for right key pecks. When baseline data were collected on the two visual stimuli during Sessions 35-40 (Experimental Phase 3), the median latencies to the green and red followed closely those already exhibited to the high tone and low tone respectively. The pigeon pecked the left key during both the high auditory stimulus and the green visual stimulus with a shorter median latency than it pecked the right key during the low auditory stimulus and the red visual stimulus; the amount of reinforcement for pecking during either visual stimulus was the same (4s). Between Sessions 40 and 45 (Experimental Phase 4) the reinforcement variable during the visual stimuli was made opposite to that during the auditory stimuli. In spite of the larger amount of reinforcement for pecks during the red stimulus condition, the bird continued to produce shorter median latencies to the green stimulus. The attempt to have the pigeon's latencies to two different set of stimuli (high/low & green/red) under the control of the reinforcement variable in opposite directions was unsuccessful during five sessions, and was abandoned. It was feared that the control by the auditory stimuli might be adversely affected. Experimental Phase 5 was a continuation of the 6s/2s difference in amount of reinforcement but with tones only.

During Experimental Phase 6, when a reversal was programmed in which the amount of reinforcement was now 2s

in the presence of the high tone and 6s in the presence of the low tone, a reversal in median latencies was obtained by Session 62, only to be lost; increasing the difference in amount of reinforcement to 2s and 8s during Experimental Phase 7 also failed to produce consistent results. A considerable difference in median latencies was produced during Experimental Phase 8 by further increasing the difference in amount of reinforcement to 1s and 8s. During Experimental Phase 9, the amount of reinforcement was changed back to 2s during the high tone and 6s during the low, with another loss in median separation; however, a return to the 1s/8s difference in amount of reinforcement during Experimental Phase 10 restored the separation. After once again changing the amount of reinforcement in the presence of the high/low tones to 2s/8s, the separation in median latencies was maintained during Experimental Phase 11.

Having demonstrated the discriminative control of the two auditory frequencies, and the control of the reinforcement variables over median latencies, attention was again turned to the use of visual stimuli during the remainder of the experiment for Bird #5670. Baseline 2 data indicated that the subject responded with a shorter median latency to the green hue (as demonstrated earlier, as well); therefore, during Experimental Phase 12, 2s of reinforcement was provided for responses to the green hue,

and 8s for responses to the red hue. Control by the reinforcement variable occurred almost immediately. The second session produced a sustained separation in median latencies in the appropriate direction. Beginning with Session 134 in Experimental Phase 13, a reversal was programmed in which responses to the green hue produced 8s of reinforcement, while responses to the red hue produced only 2s. Obtaining a reversal of median latencies proved difficult. Although there is no consistent conformance to the control by the reinforcement variable during this experimental phase, one finds an increased frequency of sessions during which there are shorter median response latencies to the green stimulus (8s reinforcement).

Bird #11948

The data for Bird #11948 are presented in Figure 6. After discrimination training in which the subject achieved a consistent discrimination index above 0.90, stable baseline data were obtained during Sessions 1-9. The attempt to demonstrate control by the reinforcement variable during Experimental Phase 1 in which pecks during the high frequency tone obtained only 3s reinforcement and those during the low frequency tone obtained 6s failed; these data do not differ from those of the previous baseline condition. During Experimental Phase 2 the amount of reinforcement obtainable to pecks during the high fre-

quency were reduced to 2s; a separation in the median latencies in the appropriate direction was achieved during the last five sessions (see Figure 6).

As with the previous subject, several sessions were conducted in Experimental Phase 3 in which, in addition to the two auditory frequencies, green and red hues were also presented on the center key, each with a probability of 0.25. Similar results were obtained in the visual stimulus baseline condition and the use of color was abandoned after Session 27. The separation in median response latencies produced during Experimental Phase 2 was lost during Phase 3; therefore, during Experimental Phase 4 the decrease in amount of reinforcement to 1s during the high tone and the increase to 8s during the low tone was programmed. As with Bird #5670, considerable separation in median response latencies was produced.

During Experimental Phase 5 median response latencies were obtained, lost, obtained again, and lost over many sessions; therefore, during Experimental Phase 6, the reinforcement variable was increased to 8s in the presence of the high tone and maintained at 2s in the presence of the low tone. The increased disparity in reinforcement conditions produced a more stable separation in median response latencies across this phase.

Reversing the reinforcement conditions associated with the two frequencies (8s in the presence of the high

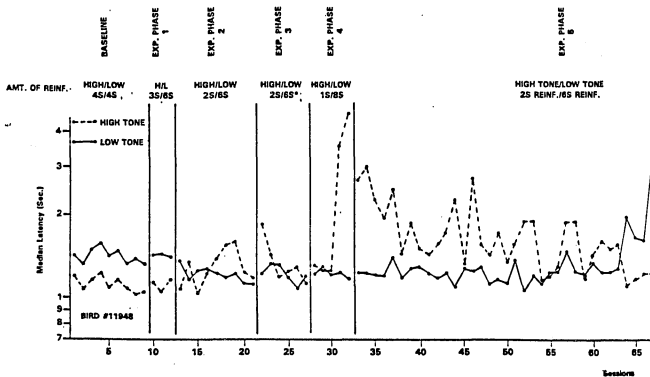
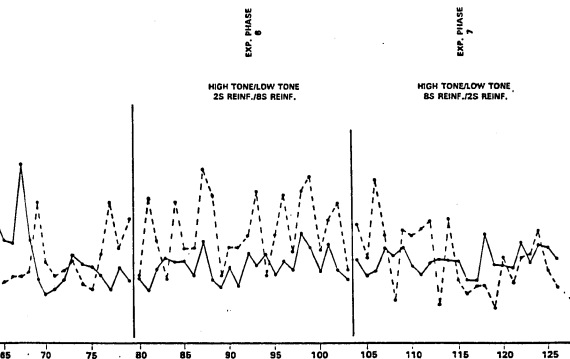


Figure 6. Experiment 2: Median Latencies for Bird #11948 Across Sessions



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tone, and 2s in the presence of the low tone) in Experimental Phase 7 produced erratic control over the median response latencies. Beginning with Session 104, a reversal was obtained in Session 108, lost to be regained again in Session 113, lost in the next session, maintained during the next five (Sessions 115-119), lost during Session 120, etc. If one looks at the entire experimental condition, however, one finds that during the last 12 sessions, the expected control by the reinforcement variable occurred in 75% of the sessions.

Bird #2683

The data for Bird #2683 are presented in Figure 7. Bird #2683 demonstrated stable median response latencies during the nine sessions of the baseline condition in which it received 4s access to food in the presence of both the high and low frequencies. Beginning with Experimental Phase 1, the amount of reinforcement during the high tone was reduced to 2s and during the low tone increased to 6s. A separation in the median response latencies, in the desired direction, was achieved in Session 18 and maintained, with few exceptions, during the entire experimental condition.

A reversal in median response latencies during Experimental Phase 2 was unsuccessful; therefore, during Experimental Phase 3 the difference between reinforcement

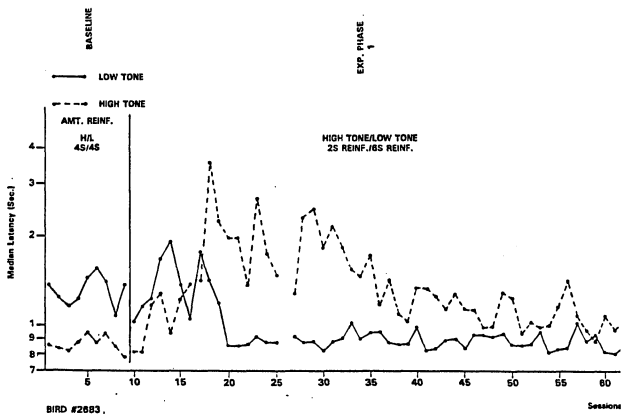
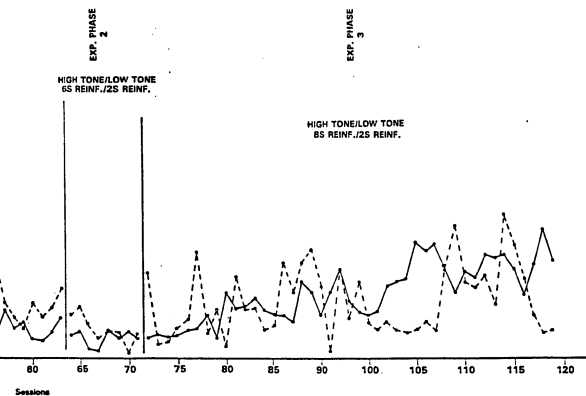


Figure 7. Experiment 2: Median Latencies for Bird #2683 Across Sessions



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conditions was increased (8s during the high tone and 2s during the low tone). If the reinforcement variable is exerting control over median response latencies between Sessions 77 & 99, the effect is not obvious from an inspection of the data (see Figure 7). There is a consistent reversal between Sessions 100 & 107, which is lost and then re- gained during Sessions 110-113, lost again to reappear in Session 117.

Although the control of median response latencies in the expected direction by the reinforcement variable was still inconsistent, it is evident from the data. During the first 20 sessions of Experimental Phase 3, median response latencies of pecks to the left key (8s reinforcement duration) were shorter in only 45% of the sessions; during the last 20 sessions, however, the percentage rose to 74%.

Bird #6493

The data for Bird #6493 are presented in Figure 8; they differ markedly from those of the other three subjects. Further, the median response latencies during Baseline, although stable, do not demonstrate one auditory stimulus as producing a systematically shorter median response latency over the other; first the high frequency and then the low frequency alternate as the shorter median latency. During Experimental Phase 1 the control by 8s

access to reinforcement in the presence of the low tone and 2s in the presence of the high tone failed to establish shorter median response latencies during the low tone. In fact, in 9 of the 15 sessions during this experimental condition just the reverse was true; shorter median response latencies were to the less favorable reinforcement condition (see Figure 8).

Failing to gain control over the median latencies after 15 sessions, the use of the auditory frequencies was abandoned. Experimental Phase 2 begins the use of visual stimuli with the same reinforcement conditions as in Experimental Phase 1 (2s access to food for key pecks during the green hue, and 8s access for key pecks during the red hue). After 4 sessions with color, the separation between the median response latencies in the desired direction was obtained; the subject pecked with longer median response latencies in the presence of the green stimulus and shorter median latencies in the presence of the red.

A reversal was programmed during Experimental Phase 3; now, 8s access to reinforcement was available during green and 2s during red. After 10 sessions, the control by the larger amount of reinforcement failed to produce shorter median response latencies in the desired direction (shorter during green).

This subject was brought under operant stimulus control via the use of the correction procedure rather than

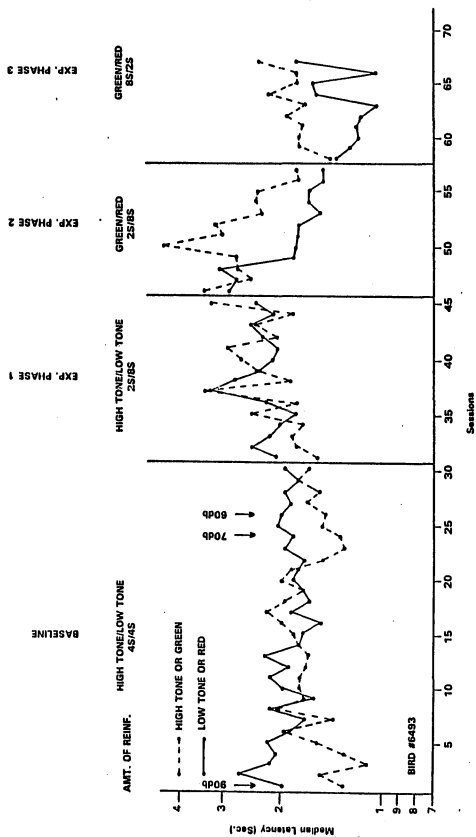


Figure 8. Experiment 2: Median Latencies for Bird #6493 Across Sessions.

the delayed-prompt procedure. Throughout the experiment, while auditory frequencies were used, the discrimination index was characteristically lower than that of the other subjects. A comparison of discrimination indices for all subjects appears in Table 6.

The mean discrimination index was computed for each experimental condition. Note that the discrimination indices are characteristically high when color is used as the discriminative stimulus.

Table 6
Comparison of Discrimination Indices

Subject	Condition	Tone	Color
#5670	Baseline 1	0.93	-
	Exper. 1	0.94	-
	Exper. 2	0.94	-
	Exper. 3	0.98	0.94
	Exper. 4	0.99	0.96
	Exper. 5	0.96	-
	Exper. 6	0.92	-
	Exper. 7	0.95	-
	Exper. 8	0.87	-
	Exper. 9	0.89	-
	Exper. 10	0.96	-
	Exper. 11	0.97	-
	Baseline 2	-	0.95
	Exper. 12	-	0.99
	Exper. 13	-	0.97
#11948	Baseline	0.95	-
	Exper. 1	0.96	-
	Exper. 2	0.90	-
	Exper. 3	0.98	-
	Exper. 4	0.96	-
	Exper. 5	0.94	-
	Exper. 6	0.97	-
	Exper. 7	0.94	-
#2683	Baseline	0.98	-
	Exper. 1	0.99	-
	Exper. 2	0.99	-
	Exper. 3	0.97	-
#6493	Baseline	0.91	-
	Exper. 1	0.82	-
	Exper. 2	-	0.98
	Exper. 3	-	0.98

GENERAL DISCUSSION

Obtaining Operant Stimulus Control

The methodology of Experiment 2 effectively dealt with the difficulties inherent in Experiment 1. The differential operant stimulus control by the auditory frequencies was demonstrated via the topographical indicator, which then permitted the investigation of the reinforcement variable's role in producing disparate median response latencies. The topographical indicator permitted the experimenter to determine when and to what extent the pigeon was under the control of the discriminative stimulus before attempting to differentially control the response latencies with the reinforcement variable. Experiment 1 did not provide this baseline. The topographical indicator was an effective technique which insured the separation of the operant stimulus control from the reinforcement variable effects. Bringing the subjects' key-pecking under the discriminative stimulus control of the auditory frequencies proved difficult, however. Much time was spent early in Experiment 2 trying various techniques to bring about the discrimination. Initially, markedly different frequencies were programmed with no success; the two stimuli were then made more different along several dimensions, frequency, intensity, and

one stimulus an unwavering tone while the other warbled. None of these strategies was successful. During Experiment 2, in which the pigeon pecked either left or right as determined by the stimulus presented on the center key, the pigeons initially stayed in front of one the two keys and pecked that key during the entire experiment, even though a time-out was imposed for errors. Given that each stimulus was presented an almost equal number of times during the session, pecking only one key gave a discrimination index of 50%. The birds were given training in pecking both keys by conducting entire sessions in which only one key was lighted and only the stimulus associated with that side key was presented. Although this improved the control by the appropriate stimuli temporarily, the subjects' performance would deteriorate and again return to the one-key strategy already described when both tones (and keys) were used. A colleague (Johnson, 1986) suggested the delayed-prompt procedure developed by Touchette (1971) to teach discriminations to retarded adolescents. Utilizing the concept of delaying the prompt, the procedure was developed and implemented successfully. Following this training, the only errors that were noted were the occasional errors that resulted from ITI responses, and later, errors that occurred when the subjects occasionally pecked the "more favorable" reinforcement key.

Control by the Reinforcement Variables

This research demonstrates that the pigeon's latencies to auditory stimuli can be brought under the control of different reinforcement conditions with the following limitations: a) many sessions were required for the control to occur initially, b) once the control by the reinforcement variable had occurred, obtaining a reversal was difficult, and c) even once control had been obtained, the control was often tenuous; there were many sessions in which the control was inexplicably lost. Much of the difficulty in obtaining reversals (in the presence of hues as well as tones) and perhaps the initial stimulus control was probably related to the pigeon having to peck only once to produce reinforcement. Although no data have systematically been collected for this ratio value (FR 1), it is believed that the number of responses required to produce reinforcement may have been an important variable. Powell (1969) found that the amount of reinforcement produced less difference between post-reinforcement pauses of short ratios than of longer ratios. Neal (1985) investigated the interaction between fixed ratio size and amount of reinforcement, and found that ratios of FR 15 produced adequate separation in median response latencies when investigating the effect of amount of reinforcement; ratios as small as FR 5 produced much less separation. Ratios

were not used in the present research because of the limitations of the experimental equipment and its programming. While waiting for response latencies to occur during the ITI, the computer checked all three keys and engage in two timing functions. Because it was slow in accomplishing all of this, occasionally the computer would be "looking" at one key when the response occurred on another. When this happened, the pigeon was required to peck again, giving an artificially long latency. In order to increase the speed of the program and eliminate these misses, the "debounce" lines of the computer program, necessary for programming ratios, were removed.

Control was brought about eventually by the extreme 1s versus 8s disparity in reinforcement. Only 1s access to reinforcement, however, placed the subject's behavior effectively on extinction (1 second gave the subject little time at the hopper) and an extremely long median latency was often the result of the subject allowing many presentations of the tone associated with the short reinforcement time simply to time out. It was thought that once a clear separation in latencies had occurred (during the 1s vs 8s) it might be maintained during less difference in reinforcement amount (2s vs 6s); such was not the case. All subjects seem to require 2s vs 8s in order to maintain an acceptable separation between median response latencies; the number of trials per session was

reduced to accommodate the large amount of reinforcement earned.

Intrusion by Elicited Responses Eliminated

Had responses been made to the center (stimulus) key, they would be considered elicited or autoshaped responses; none occurred in the use of auditory stimuli, and very few occurred to the visual stimuli. (Once every few sessions there would be a response in the case of one bird used in the previous visual stimulus research). Median latencies and separation of median latencies were obtained without the intrusion of autoshaping. Several features of the research in Experiment 2 worked against the development of autoshaped responses to either the stimulus or the response keys. Of the many variables that seem to facilitate autoshaping, the one that seems most relevant in Experiment 2 is that the key stimulus and the stimuli associated with the hopper operation must be similar in their more salient features (Fisher & Catania, 1977; Sperling, Perkins, & Duncan, 1977; Steinhauer, Davol, & Lee, 1977; Sperling & Perkins, 1979; Steinhauer, 1982). In the more common examples of autoshaping, the hue presented on the stimulus key and that presented in the hopper opening are similar; the more similar they are, the more effective the autoshaping procedure will be. In the use of both the auditory and visual stimuli this facilita-

tive condition was not met. As already mentioned, the pigeon generally resists pecking an unlighted key; during the auditory stimulus presentations the key was non-illuminated. For autoshaped responses to occur to the center key, there would have had to be a stimulus change on that key that was associated with some similar change in the stimuli associated with the food presentation. In the use of auditory stimuli, there were no tones associated with the hopper operation; when hues were presented on the center key, elicited responses also did not occur because of the non-illumination (and dissimilarity) of the hopper opening.

Role of Stimulus Intensity

The role of the intense stimulus level (90 db), in the present research, is unclear. If the pigeons were pecking the response key to terminate an aversive level of auditory stimulus, that might account for the failure to produce clear separation in the median response latencies in Experiment 1 and some of the difficulty in demonstrating control by the reinforcement variable in Experiment 2. The termination of the stimulus may have obscured the influence of the reinforcement variable, particularly if the reinforcement variable's effect was already weakened by requiring only a single response to produce reinforcement. At the very least, there may have been a contributory

effect of the tone offset. Further, even though both tones were measured to be physically equal (within 3-5 db), the relative aversiveness of the two tones is unknown; one tone might have controlled more rapid escape responding than the other because of its loudness. Other researchers have used similar intensities without reporting undesirable effects (Rudolph & Van Houten, 1977; Steinhauer, 1982; Steinhauer, Davol, & Lee, 1977); however, their investigations were not designed to identify differences between reinforcement by escape and reinforcement by presenting food. Should the intensity of the auditory stimuli be an important variable, duplication of Experiment 1 with less intense auditory stimuli might produce markedly different results.

Bird #5670's behavior merits special mention. This bird has been used in previous research involving color. During all of that research the bird was one of the most tractable of subjects, easy to handle, getting into the carrying container with "enthusiasm." After the auditory research was well underway, this bird resisted efforts to move it from home cage to chamber, attacked the handler with beak and wings, and would bite (hanging on and twisting) its own wing if unable to make contact with the handler. After the cessation of the auditory research and the beginning of the visual portion of the research, the bird became considerably easier to handle and less aggres-

sive. Suggestions at this point are very speculative. However, with the intensity of the auditory stimulus for much of the research at 90 db, this atypical behavior may be another hint of the aversiveness of the stimuli. The other pigeons in the research did not develop similar behaviors; however, Bird #5670 was a subject for many more sessions than any other bird.

Errors and the Discrimination Index

When errors were made in Experiment 2, after an acceptable discrimination index was obtained in preliminary training, the errors seemed to occur in two ways: First, inspecting the pigeon in the chamber, one finds that some responses are started during the ITI and finished at the onset of the stimulus, but not under the control of the stimulus; the pigeon had started its response and "happened" to peck the wrong key at the moment of stimulus onset. Characteristically, these responses would produce abnormally short latencies (under 0.30s). Secondly, in the presence of the "unfavorable" stimulus condition, the pigeon would occasionally peck the key associated with the more favorable reinforcement condition. Under these conditions, the pigeon would often wait a considerable interval before pecking the wrong key. The role of these errors in an interpretation of the data is not clear. Latencies of error responses were not re-

corded, but had they been to the correct key and been recorded, may have increased the median response latency value associated with the less favorable reinforcement condition.

Difficulty in Eliminating ITI Responses.

The difficulty cited by Stebbins (1970) regarding the pigeon's tendency to peck during "quiet" periods before the start of a trial was dealt with through the use of the intertrial-interval contingency. Should the pigeon peck during the ITI, the interval was reset. Further, by varying the length of the intervals, a temporal discrimination was difficult. And finally, the varying length intervals in the beginning of the training were made very large to reduce the probability that any one key peck would be closely followed by the onset of the stimulus condition for the trial. As the pigeon's tendency to peck during the ITI diminished, the interval was made progressively shorter until the v5s ITI used in the research was reached. This procedure was utilized with all birds for both experiments. The subjects varied throughout the experiment in regard to their tendency to peck during the ITI. There may be several reasons for the ITI contingencies failure to suppress all pecking: (a) The previously mentioned situation in which the pigeon starts the peck during the ITI and completes it during the trial, (b)

There were a few trials noted during which the computer "missed" the response, allowing the trial to start even though a peck had occurred at the end of the ITI, thus, adventitiously reinforcing responses during the ITI, and (c) At least one subject engaged in "feints" to the response keys during the ITI; some of these responses accidentally made contact.

Role of Species-Specific Factors.

Foree and LoLordo (1973) as reported by Mackintosh (1977) found that when pigeons were reinforced with food or with escape from electric shock by treadle pressing, they were more likely to respond to an illuminated stimulus when reinforced with food, but to a tone when reinforced with escape from shock. "At the very least, these results suggest that the well-known difficulty in establishing control over food-reinforced key pecking in pigeons by an auditory stimulus...cannot be entirely attributed to defects in the birds' sensory system." (Mackintosh, p. 485). However, one might find that the species is predisposed by evolutionary evolution or strong previous history with hues as evocative stimuli associated with pecking for food, and auditory frequencies as evocative stimuli associated with some other behavior not associated with food. Although operant stimulus control was well-established in Experiment 2, the ease

with which it is accomplished with visual stimuli, and the difficulty in accomplishing it with auditory stimuli, may be partially related to compatibility or incompatibility between discriminative operants and the reinforcers they produce.

Use of Visual Stimuli

Research with the hues was abandoned because of a concern that it might interfere with research with the auditory stimuli. Furthermore, there was some indication that the subjects' responses to the hues were being dominated by the responses to the tones. That is, if the pigeon already pecked the left key with shorter median latencies when under the control of the high frequency, it would peck the left key with shorter median latencies in the presence of the hue associated with the left key (green) in spite of a more favorable reinforcement condition on the right key (red). It was determined that attempts to establish separate control over both auditory and visual stimuli might better be postponed for later research. Although the research was not designed to investigate the difference in the control of latencies by auditory and visual stimuli, the data suggest that the pigeon is more quickly controlled by reinforcement variables associated with visual stimuli than auditory stimuli.

Conclusion

The goal of this research was to arrange an experimental setting in which one could study the effects of reinforcement variables on response latencies that were completely under operant stimulus control, by eliminating the intrusion of autoshaped, elicited control. That goal was achieved.

In addition, the investigation has suggested some areas for further research: (a) The suggestion that the 90 db stimulus might be operating as a negative reinforcer for key pecks needs further attention if research with auditory stimuli continues, and (b) when stimulus control is obtained quickly and easily, there isn't an opportunity to watch its progress and identify the most effective way to bring it about. Because of the apparent difficulty in teaching the pigeons to discriminate between auditory stimuli, investigating discrimination training methods (comparing correction-trial with delayed-prompt, for instance) should prove interesting.

FOOTNOTES

1. At the time this research was conducted there was an undiscovered error of 10 db in the sound-pressure meter (Type 1551-C Sound Level Meter, General Radio Co.) used to calibrate the intensity of the stimulus. Experiment 1 and most of Experiment 2 were conducted with what was thought to be 80 db tones, when they were actually 90 db. The possible significance of this will be treated in the Discussion. All references to decibel levels are made using the corrected value.

2. This pellet was used because (a) the pigeons were earning their entire daily food ration in the chamber which necessitated providing a more balanced diet than grain provides, and, (b) the addition of grit in the home cage was unnecessary. No data have been gathered, but casual observation suggests that the maintenance of the deprivation weight is easier without the addition of non-nutritive grit to the diet.

3. In research previously cited in which an unlighted key was used with auditory stimuli, the researchers (Rudolph & Van Houten, 1977) first trained the pigeons to peck a lighted key and then faded the light out gradually.

Appendix A

Experiment 1: Computer Program

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259 POKE RD,152
278 IF V1=200 THEN FF=8 THEN 200
280 POKE RD,24
279
2800 REM #88 COLLECT DATA SECTION #88
281 REM
282 IF PKA="R" THEN PRINT " *K2:
283
286 PRINT
287
288 IF S=56 THEN AC1=1
289 IF S=88 THEN AC1=2
290 IF PKA="C" THEN AC1=3
291 IF PKA="H" THEN AC1=3
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293 C1=C1+1
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Appendix B

Experiment 2: Computer Program

[illegible]

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