AUDITORY WORD DISCRIMINATIONS IN THE PIGEON

RICHARD PISACRETA, DAVID GOUGH, EDWARD REDWOOD, AND
LEE GOODFELLOW

FERRIS STATE COLLEGE

Four pigeons were trained on a multiple variable-interval 30-s extinction schedule with various pairs of spoken English words presented as the discriminative stimuli. The birds typically produced discrimination indices of 70% to 90% accuracy. Discrimination accuracy was improved by shortening the interval between auditory stimulus presentations, and by increasing the number of syllables in the words.

Key words: word discriminations, auditory discriminations, multiple schedules, key pecks, pigeons

After the initial psychophysical studies employing auditory stimuli (e.g., Heinemann & Avin, 1973; Irwin & Terman, 1970; Jenkins & Harrison, 1960; Pierrel & Sherman, 1960; Pierrel, Sherman, Blue, & Hegge, 1970; Terman, 1970), the literature on complex auditory stimuli has become scarce relative to the experiments that have employed visual stimuli. Recently, however, there has been renewed interest in both the auditory systems of birds (Abs, 1983) and in their complex auditory discriminative capabilities (e.g., D'Amato & Salmon, 1982; Hulse, Cynx, & Humpal, 1984; Pepperberg, 1983; Porter & Neuringer, 1984; Stebbins, 1983; Thompson & Herman, 1981).

Heinemann and Avin (1973) trained pigeons to peck one response key if white noise was present at any of five intensities equal to or greater than 86 dB, and to peck a second key if the noise level was any of five intensities lower than 86 dB. After a few days of training, the birds emitted over 90% of their responses on the correct key. D'Amato and Salmon (1982) trained monkeys to discriminate between two tunes. Responses were reinforced on a fixed-interval 10-s schedule (FI 10) in the presence of a six-note (1.8-s duration) tune (S^D). Extinction was in effect when a 33-note (2-s duration) tune (S^Δ) was present. The average discrimination index [(S^D rate/S^D + S^Δ rate) × 100] that resulted was 84.5%. Later, within the same study, rats acquired the discrimination more quickly than the primates had, with a mean discrimination index of 79.7%. Hulse et al. (1984) reported data on starlings' discriminations between sound pitches and rhythms.

Porter and Neuringer (1984) demonstrated that pigeons can discriminate between two pieces of classical music. The 1-min S^D components were accompanied by a flute piece by J. S. Bach, and key pecks were reinforced according to a fixed-ratio 15 (FR 15) schedule. The randomly alternating S^Δ (extinction) periods were accompanied by a viola piece by P. Hindemith. The resulting discriminative indices ranged from 77% to 89%. Later in the study, the pigeons were trained to peck one response key if a Bach piece was present and a different response key if a Stravinsky piece was playing. Reinforcers were delivered on a variable-interval 30-s (VI 30) schedule; this procedure produced 70% to 75% accuracies.

The present study attempted to ascertain whether pigeons could discriminate between spoken English words, and to assess how the word length (number of syllables) and the frequency of word presentation influenced their performances.

EXPERIMENT 1

The first experiment established an auditory discrimination with tones in order to replicate previous studies with our apparatus, and then compared discriminations based upon

tones to discriminations based upon spoken words as stimuli.

METHOD

Subjects

Subjects were 4 White Carneaux pigeons, maintained at 80% ± 15 g of their free-feeding weights. Pigeons B7, B8, and B9 had been trained previously on a conditional-discrimination task employing visual stimuli (Pisacreta, Redwood, & Witt, 1984). Pigeon B6 was trained previously on a simultaneous-discrimination procedure involving red and green hues. None of the birds had been exposed to the auditory stimuli or procedures used in the present study. Depending on their weights, the birds were trained during two or three consecutive experimental sessions, Mondays through Fridays. There was an intersession interval of approximately 5 min while the experimental data were recorded.

Apparatus

The apparatus was a 35- by 35-cm operant chamber enclosed in a sound-attenuating hull. The response panel, 37 cm by 35 cm, had eleven 2.7-cm response keys (BRS/LVE Model #121-16). Throughout the experiment, only the response key located 5 cm above the feeder was lighted. During each session, a black circle presented on a white background was rear-projected onto the key by means of an Industrial Electronics Engineers inline projection (Model #1813-1820). The key was darkened between sessions. The operating force of the key was approximately 0.16 N. The feeder (BRS/LVE Model #114-10) provided 3-s access to grain. The houselight, a GE #1820 lamp located in the upper left corner of the response panel, provided additional light throughout each experimental session. A ventilation fan masked extraneous noise.

A speaker located 8 cm to the left of the feeder provided the auditory stimuli. The tone and word stimuli were generated by an electronic speech synthesizer, the ELECTRIC MOUTH® (Netronics R&D Ltd.), and were presented at a measured intensity of approximately 75 dB. The pairs of word stimuli were chosen by the authors and were perceived by them and by three other human listeners as having the same duration (hereafter referred to as word length), tonal quality, and voice inflection. An E and L Instruments MMD-1

computer and additional hardware recorded data and controlled experimental events.

Procedure

Phase 1. The first 20 sessions of the experiment allowed each bird to produce 40 reinforcers per session on a VI 15-s schedule. For Birds B6 and B9, an 80-Hz tone of 500-ms duration was presented every 3 s. A 400-Hz tone was provided for Birds B7 and B8. The speech synthesizer was programmed to operate in its silence mode between stimulus presentations. During this and all subsequent phases of the experiment, reinforcers were not produced while an auditory stimulus was present. Thus, key pecks were reinforced only during the silent periods between consecutive S^D presentations.

Phase 2. The birds were placed on a multiple VI 15-s extinction (EXT) schedule for 40 sessions. The S^D components were 1 min in duration. During this and all subsequent phases, the stimuli did not change from S^Δ to S^D until at least 2 s had elapsed since the last key peck. Therefore, the S^Δ periods were at least 1 min in duration but could be longer, depending on the bird's behavior. A reinforcer could not be produced during the first 5 s of each S^D component, thus ensuring that the S^D was presented at least once before a response was reinforced. The S^D and S^Δ components were randomly alternated. S^D or S^Δ could be presented for as many as three consecutive periods. For Birds B6 and B9, the 80-Hz and 400-Hz tones served as the S^D and S^Δ, respectively. For Subjects B7 and B8, the 400-Hz tone was presented as S^D and the 80-Hz tone signaled the S^Δ component.

Phase 3. For the next 20 sessions, a multiple VI 30-s EXT schedule was in effect. This served as the baseline schedule for the remainder of the study.

Phase 4. For 15 sessions, the tones were replaced with a pair of two-syllable words. For Birds B6 and B9, "percent" and "number" served as S^D and S^Δ, respectively (word length = 320 ms), and were presented at 3-s intervals. In order to counterbalance, B7 and B8 were trained with "number" (S^D) and "percent" (S^Δ). During this and all subsequent phases of the study, the S^D and S^Δ provided for B6 and B9 were always presented as the S^Δ and S^D, respectively, for B7 and B8.

Phase 5. During the next 25 sessions, the

birds were trained with a second pair of two-syllable words (word length = 340 ms); "zero" and "again" served as the S^D and S^Δ, respectively, for B6 and B9.

Phase 6. For the next 15 sessions, the tone stimuli used in Phases 2 and 3 were again presented as S^D and S^Δ to compare discriminations based upon tones with those based upon words as discriminative stimuli.

Phase 7. To assess if the time between consecutive S^D or S^Δ presentations was influential, the interstimulus interval (ISI) between consecutive tones was reduced from 3 s to 1 s for 25 sessions.

RESULTS AND DISCUSSION

Figure 1 presents each bird's response rates during S^D and S^Δ for the first 10 sessions of Phases 2 through 7. The first panel (Phase 2) shows that differential responding began to occur reliably within three to seven sessions. A *t* test for related measures (the differences between S^D and S^Δ rates generated by each bird during the 10th session of Phase 2) was statistically significant, $t(3) = 4.17$, $p < .05$. Introducing the VI 30-s schedule (Phase 3, second panel) disrupted the differential performance of only Bird B6. However, all birds continued to respond at significantly different rates during S^D and S^Δ, $t(3) = 4.92$, $p < .02$ (first session). The data generated during the first session of Phase 4 (third panel), in which the first pair of word stimuli was introduced, did not show a statistically significant difference, $t(3) = 1.22$, $p > .10$. Similar results were obtained during the first session of Phase 5 in which a different pair of words was used, $t(3) = 2.44$, $p > .10$. However, each bird was reliably responding differentially to the word stimuli by the 10th session of Phase 4 and Phase 5. Reintroducing the tone stimuli in Phase 6 did not produce a disruption in differential response rates. The differences between S^D and S^Δ rates during the first session of Phase 6 were statistically significant, $t(3) = 14.47$, $p < .001$; the differential response rates produced during the first session of Phase 7 were also statistically significant, $t(3) = 5.27$, $p < .02$.

Figure 2 presents the S^D and S^Δ rates for successive blocks of sessions throughout each phase of the experiment. The figure shows that after initial acquisition, each bird continued to produce differential response rates

throughout each phase. Panels 2 and 3 (Phases 2 and 3) reveal that each bird reliably responded differentially to the tones, and Panels 4 and 5 (Phases 4 and 5) show that differential S^D and S^Δ rates were consistently maintained with words as discriminative stimuli. A subjects-times-treatments, repeated-measures analysis of variance (ANOVA) of Phase 3 (tones) and Phases 4 and 5 (words) was not statistically significant, $F(2,6) = 2.45$, $p > .20$, indicating that the birds discriminated tone and word stimuli equally well.

With the exception of Pigeon B9, reducing the ISI from 3 s to 1 s during Phase 7 yielded a 14% to 24% increase in the discrimination index. This resulted mainly from a decrease in S^Δ rates.

EXPERIMENT 2

The second experiment was an attempt to assess the effects of word length on the birds' discriminative performances. This was accomplished by presenting pairs of one-, two-, or three-syllable words as the discriminative stimuli.

Subjects and Apparatus

Subjects and apparatus were the same as those described in Experiment 1.

Procedure

Phase 1. For 40 sessions, a new pair of two-syllable words, "forward" and "reverse" (word length = 320 ms), were presented. They served as the S^D and S^Δ stimuli, respectively, for Birds B6 and B9, and as the opposite functions for Pigeons B7 and B8. The interstimulus interval was 1 s, as in Phase 7 of Experiment 1.

Phase 2. Two three-syllable words, "intruder" and "seventeen" (word length = 500 ms), were provided during the 35 sessions of this phase.

Phase 3. During each of the next 50 sessions, two letters of the alphabet served as the discriminative stimuli, "U" and "F" (letter length = 300 ms). Pigeon B6 developed a respiratory infection and was consequently retired for the last 20 sessions of this phase.

Phase 4. The letters were replaced by two one-syllable words, "time" and "volt" (word length = 240 ms), for the next 40 sessions.

Phase 5. A new pair of two-syllable words, "gallon" and "limit" (word length = 300 ms)
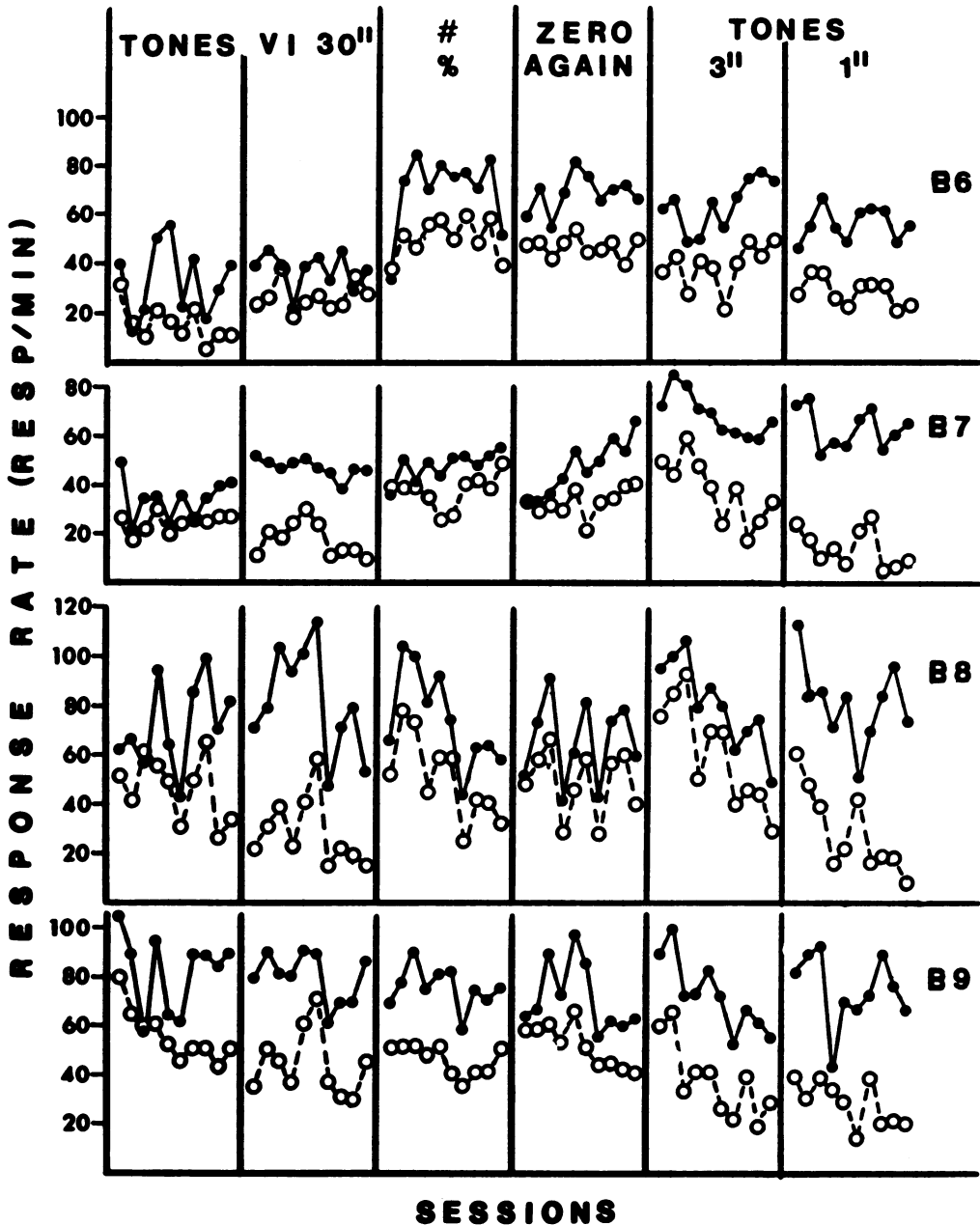
Fig. 1.   Response rates during S^D (filled circles) and S$^\Delta$ (open circles) for the first 10 sessions of Phases 2 through 7 of Experiment 1. The discriminative stimuli used are indicated at the top of each panel.

were presented during each of the next 25 sessions.

Phase 6. The time between consecutive auditory stimulus occurrences was increased to 3 s in order to again assess the influence of ISI. The words "gallon" and "limit" contin-

ued to serve as the discriminative stimuli during each of these 25 sessions.

RESULTS AND DISCUSSION

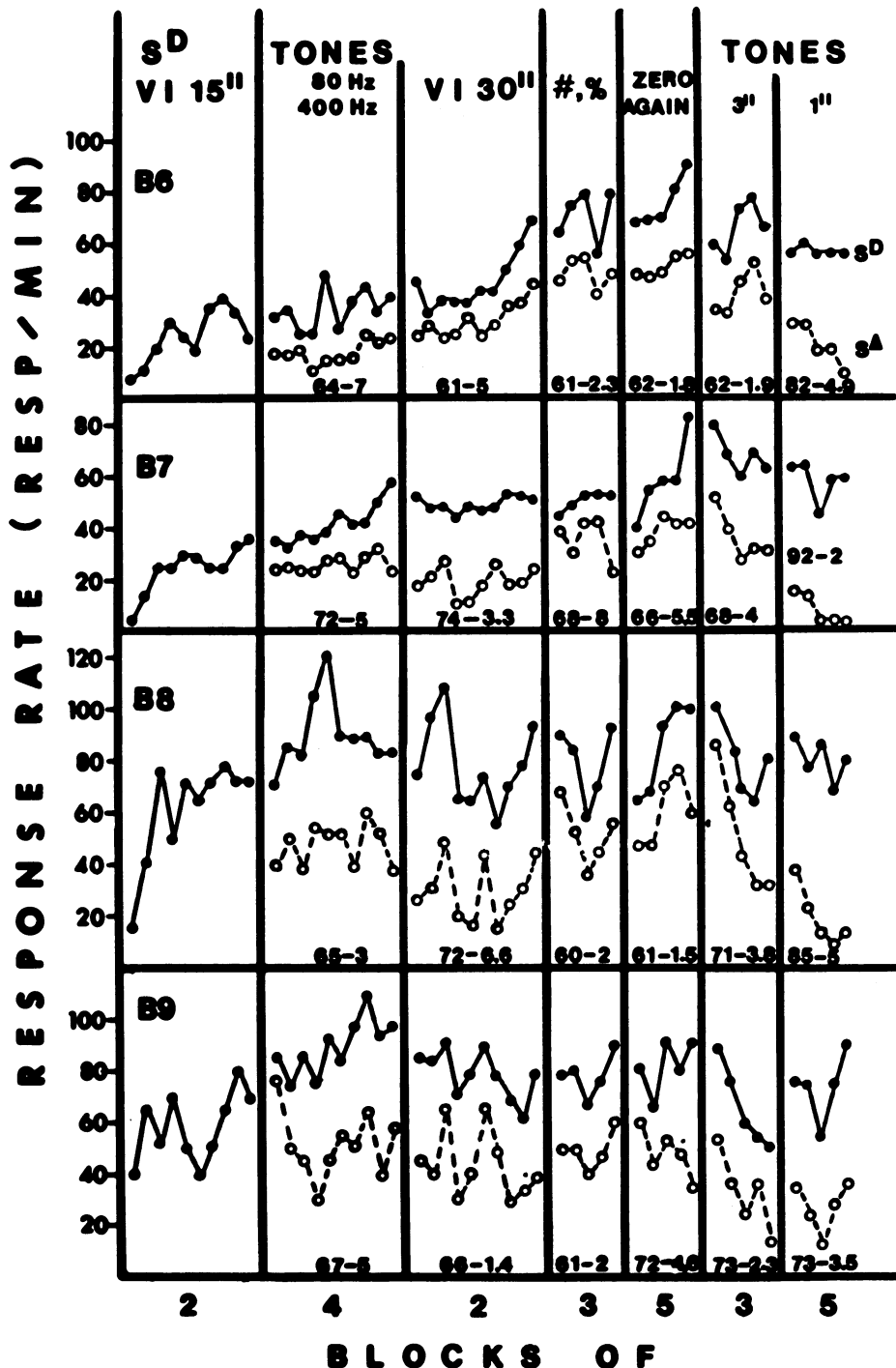Figure 3 presents the response rates produced during the first 10 sessions of each phase

Fig. 2. Mean response rates during S^D (filled circles) and S^Δ (open circles) for successive blocks of sessions during each phase of Experiment 1. The numbers at the bottom of each panel represent the mean discrimination index and its standard deviation computed over the last five sessions of each phase. The discriminative stimuli used are presented at the top of each panel.
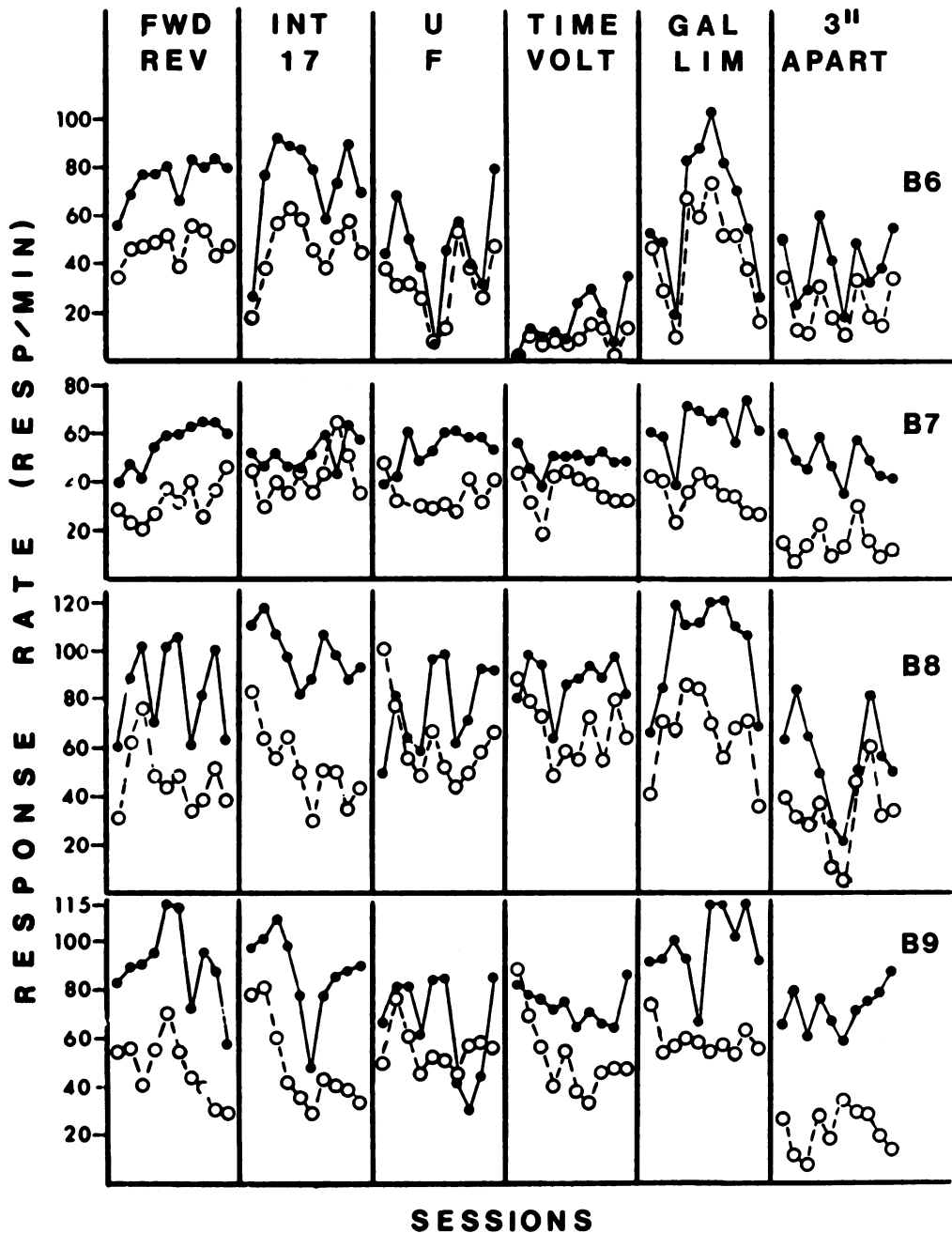
Fig. 3. Response rates during S^D (filled circles) and S^Δ (open circles) from the first 10 sessions of each phase of Experiment 2. The auditory stimuli include: forward (FWD), reverse (REV), intruder (INT), seventeen (17), gallon (GAL), and limit (LIM).

of Experiment 2. The first panel shows that each bird produced differential response rates during each of the first 10 sessions of Phase 1, $t(3) = 4.86$, $p < .02$ (first session). Although the S^D and S^Δ rates were more con-

verged during the initial sessions of Phase 2 relative to Phase 1, their difference continued to be statistically significant, $t(3) = 3.28$, $p < .02$ (first session).

This was not the case, however, when the

letters "U" and "F" were introduced in Phase 3. The S^D and S^Δ rates were not significantly different during the first session, $t(3) = 0.65$, $p > .50$, but they became significantly different during the third session, $t(3) = 5.29$, $p < .02$. Similar results were produced during the initial sessions in Phase 4, in which the stimuli were "time" and "volt." The S^D and S^Δ rates were not significantly different during the first session, $t(3) = 0.16$, $p > .50$, but were significantly different during the third session, $t(3) = 3.71$, $p < .05$.

The S^D and S^Δ response rates were significantly different during the first session of Phase 5 ("gallon" and "limit"), $t(3) = 3.61$, $p < .02$, and during the first phase of Phase 6 in which ISI was increased to 3 s, $t(3) = 3.75$, $p < .02$.

Figure 4 presents each bird's S^D and S^Δ rates for successive blocks of sessions throughout Experiment 2. The figure shows that after acquisition, each bird continued to respond differentially throughout each phase. Panel 1, Phase 1 reveals that with the exception of Bird B6, each subject's discrimination index was higher with the new two-syllable words, "forward" and "reverse," than in Phases 4 and 5 of Experiment 1. This may be due to extended training or to the lower ISI value—1 s instead of 3 s. Providing longer, three-syllable words in Phase 2 (Panel 2) produced an increase in the discrimination indices of Birds B6, B8, and B9, whereas shortening the auditory stimuli to letters in Phase 3 (Panel 3) yielded a discriminative deficit in all birds.

The additional one-syllable words "time" and "volt" (Phase 4, Panel 4) produced discrimination indices for Birds B7, B8, and B9 that were lower than those produced by the two- or three-syllable words presented earlier. Providing a new set of two-syllable words (Phase 5) resulted in improved discriminative performance for each bird. A subjects-times-treatments (Phases 1–5) ANOVA proved significant, $F(4,12) = 3.41$, $p < .05$, indicating that the different sets of stimuli maintained reliably different levels of discriminative performance. Finally, increasing the ISI to 3 s in Phase 6 produced a decrease in the S^D rates produced by each of the birds.

Experiment 2 expanded on the results of the first experiment. Pigeons can learn to discriminate between various pairs of auditory word stimuli. Furthermore, Experiment 2 demonstrated that the length of the auditory stimuli as well as the time between repetitions influenced the accuracy of discrimination.

EXPERIMENT 3

Experiment 3 included four additional manipulations. The S^D and S^Δ words were repeated during each presentation—for example, "gallon-gallon" and "limit-limit"—in an attempt to determine whether the birds would respond to the double word as the same word repeated, as would be suggested by an increase in their indices of discrimination, or as new stimuli, which would be indicated by a convergence followed by separation of the S^D and S^Δ rates. The second manipulation paired two auditory stimuli formerly presented as S^D. If the birds remembered the stimuli, we expected to see an initial high rate in both components followed by a gradual decrease in the S^Δ rates. Similarly, the next phase paired two former S^Δ. If the birds remembered the stimuli, we expected to see an initial low rate in both components followed by an increase in the S^D rate. The final manipulation eliminated the auditory stimuli in order to ensure that the birds' differential response rates were attributable to stimulus control by the auditory stimuli and were not the result of some other experimental variables such as schedule cues.

METHOD

Subjects and Apparatus

Subjects and apparatus were the same as those used in Experiments 1 and 2, except that Bird B7 developed a respiratory infection and was retired.

Procedure

Phase 1. The same conditions presented in Experiment 2, Phase 6 ("gallon" and "limit," 3-s interval between presentations) were continued for 45 sessions, with one change: The S^D and S^Δ stimuli were each repeated (word length = 710 ms) every 3 s. For Birds B6 and B9, the S^D and S^Δ were "gallon-gallon" and "limit-limit," respectively. For Pigeon B8, the stimuli served the reverse function. Bird B8 developed a respiratory infection and was subsequently retired during the last 21 sessions of Phase 1.

Phase 2. For the next 15 sessions, two new words were presented, "system" and "correct" (word length = 370 ms).
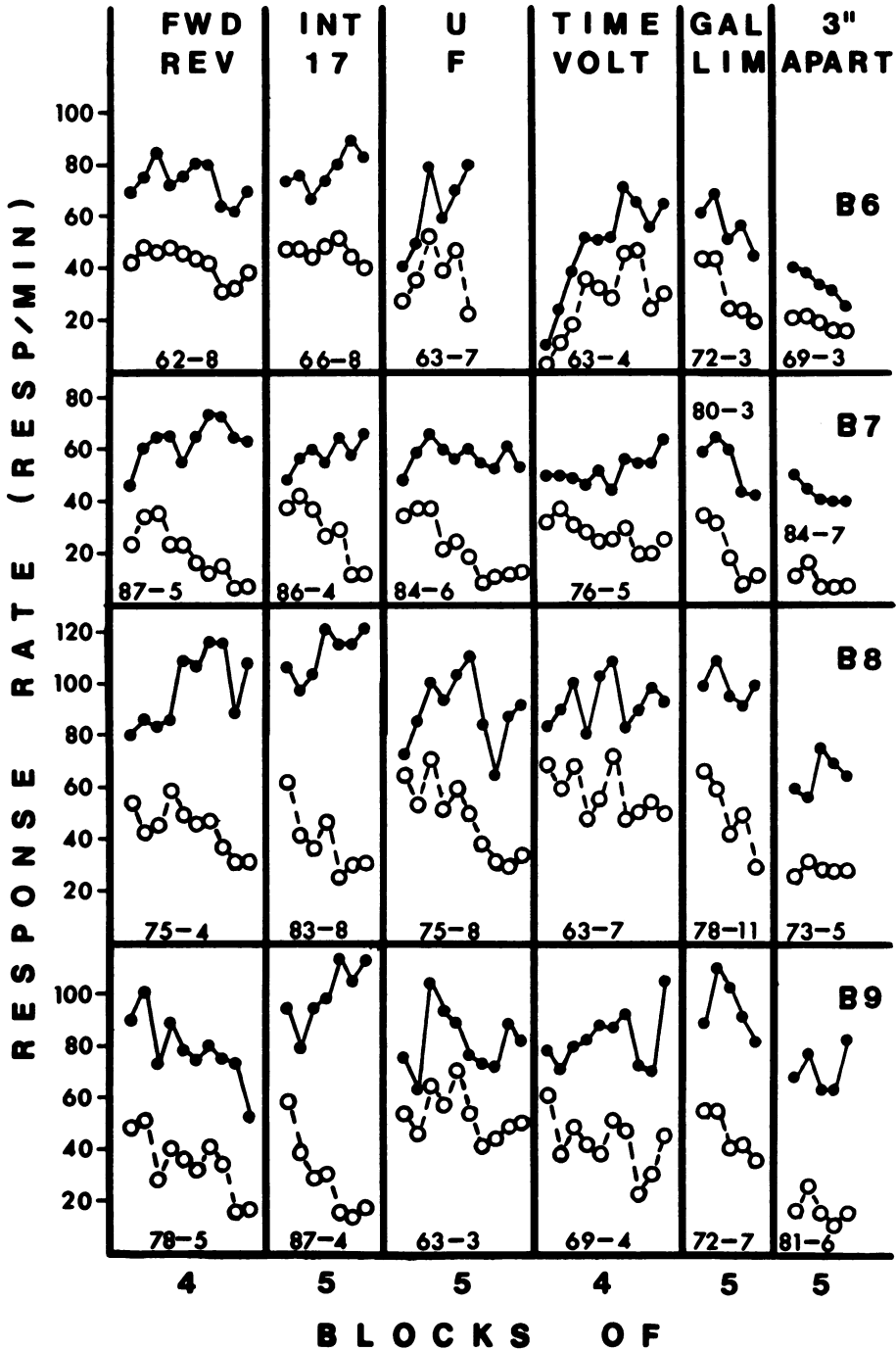
Fig. 4. Mean response rates during S^D (filled circles) and S^Δ (open circles) for successive blocks of sessions during each phase of Experiment 2. The mean discrimination index and its standard deviation, computed over the last five sessions of each condition, are shown in the bottom of each panel.

Phase 3. The next 25 sessions repeated the double-word conditions of Phase 1. The S^D and S^Δ (word length = 750 ms) for Birds B6 and B9 were "system-system" and "correct-correct," respectively.

Phase 4. The next nine sessions involved pairs of words formerly used as S^D in Experiment 1. For Birds B6 and B9, the S^D and S^Δ were "number" and "again," respectively. Bird B8 was trained with "percent" (S^D) and "zero" (S^Δ). The word lengths of the stimuli were 320 ms and 340 ms, respectively.

Phase 5. During the next nine sessions, all stimulus words formerly presented as S^Δ in Experiment 1 were used. For Birds B6 and B9, the S^D and S^Δ were "percent" and "zero," respectively; for Bird B8, the S^D was "number" and the S^Δ was "again." Pigeon B8 again exhibited signs of illness and was therefore retired from the experiment.

Phase 6. The next 15 sessions employed new two-syllable words, "thirty" and "hundred" (word length = 300 ms).

Phase 7. The last 15 sessions of the study did not include auditory stimuli. The birds were trained on a mixed VI 30-s EXT schedule. During this phase, the speaker was disconnected from the speech synthesizer.

RESULTS

Figure 5 presents the S^D and S^Δ rates obtained during the first 10 sessions of each phase of Experiment 3. The data in Panel 1 (Phase 1) show that for 2 of the 3 birds (B6 and B8), the words functioned as novel stimuli rather than as familiar words presented twice. First-session differences between S^D and S^Δ rates were not statistically significant, $t(2) = 1.96$, $p > .10$. Introducing the words "correct" and "system" in Phase 2 resulted in no consistent difference between S^D and S^Δ response rates during the first session of Phase 2, $t(2) = 0.24$, $p > .50$. However, as training progressed, the two rates moved apart and their difference had become statistically reliable by the fifth session, $t(3) = 4.56$, $p < .05$. Similar to the results obtained in Phase 1, repeating the auditory stimuli during Phase 3 (i.e., "correct-correct" and "system-system") did not yield significantly different response rates during the first session, $t(2) = 2.13$, $p > .10$, although the observed difference was in the predicted direction for each bird. Statistically significant differences did not emerge until the 10th session, $t(2) = 5.07$, $p < .05$.

Providing pairs of words that were previously presented as S^D and S^Δ during Phases 4 and 5 did not produce data that suggested enduring stimulus control from earlier training. First-session data from both phases were not statistically significant, $t(2) = 3.78$, $p > .10$ (Phase 4) and $t(1) = 2.63$, $p > .10$ (Phase 5), although the current S^D rates were higher than the current S^Δ rates in each case. As before, differential response rates became clearly evident after a few sessions of training. Introduction of a new set of words during Phase 6 required six sessions of training before the differences between response rates were statistically significantly different, $t(1) = 12.71$, $p < .05$. Finally, each bird's response rates during the two scheduled components differed consistently when no auditory stimuli were provided during Phase 7.

Figure 6 shows the response rates (in blocks of sessions) produced during each phase of Experiment 3. A comparison of Phases 1 and 3 of Figure 6 with Phase 2 of Figure 6 and the last panel of Figure 4 reveals that double-word auditory stimuli generally produced greater differentiation between S^D and S^Δ response rates than was observed with single-word stimuli. Session-by-session ANOVAs across the four phases (i.e., comparing the discriminative indices for the first session of each of the four phases; the second session of each phase, etc.) frequently proved significant. For example, an ANOVA comparing measures from the last session of each of the four phases proved statistically significant, $F(3,6) = 5.43$, $p < .05$. The increased differentiations of rate in Phases 1 and 3 of Experiment 3 suggest that the word stimuli exerted more stimulus control when they were repeated during each presentation. As before, the birds learned to reliably discriminate between new words, "correct" and "system" (Phase 2) and "thirty" and "hundred" (Phase 6).

The results were not as expected when the former S^D stimuli were presented in Phase 4. Each bird maintained a differential response rate that suggested that the words were responded to as new stimuli. Curiously, presentations of the two former S^Δs (Phase 5) produced increases in the response rates in both components for both birds.
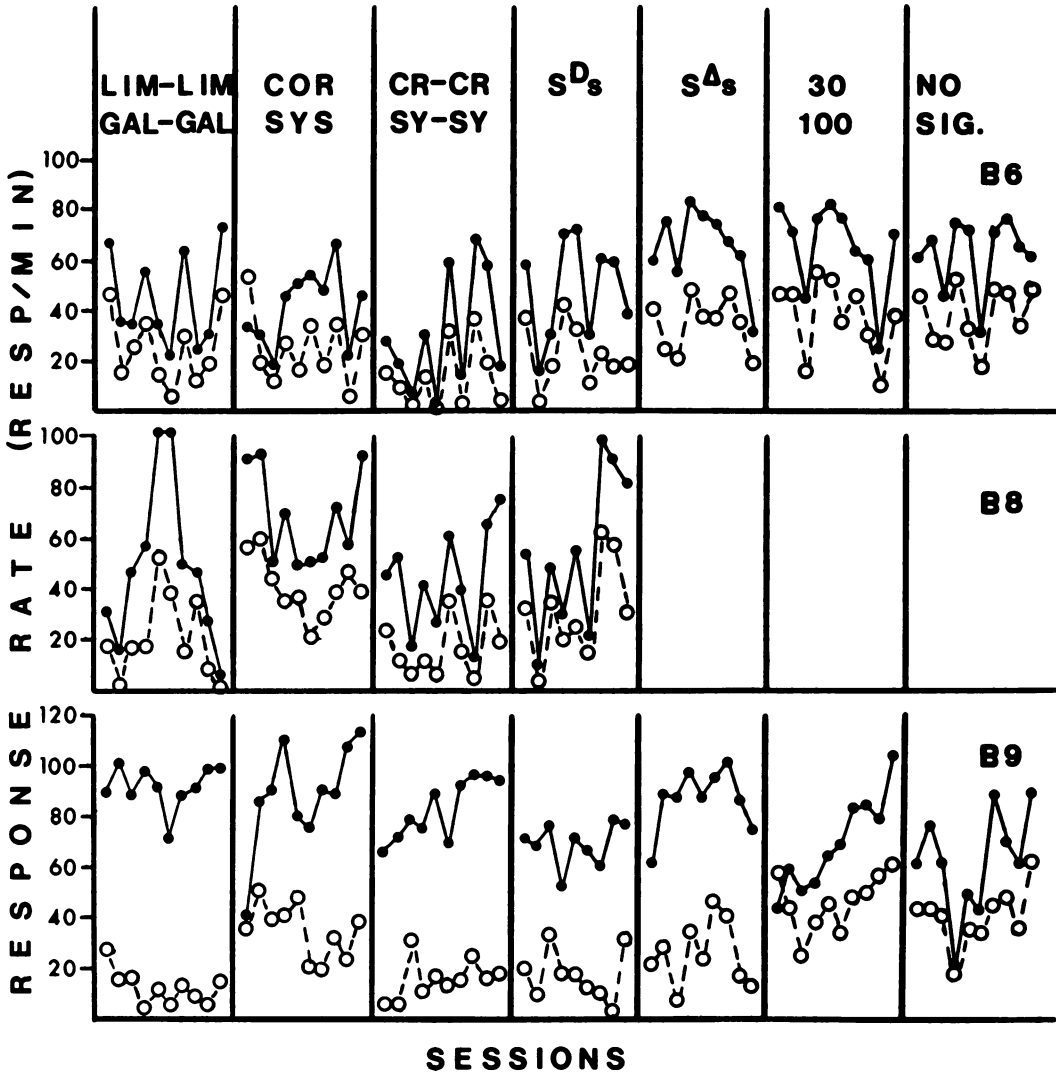
Fig. 5. Response rates during S^D (filled circles) and S$^\Delta$ (open circles) for the first 10 sessions of each phase of Experiment 3. The auditory word stimuli included: limit-limit (LIM-LIM), gallon-gallon (GAL-GAL), correct (COR), system (SYS), correct-correct (CR-CR), system-system (SY-SY), and the spoken numbers thirty and hundred. NO SIG. denotes the last phase in which no auditory stimuli were presented and a mixed VI 30 EXT schedule was in effect.

During Phase 7, the mixed VI 30 EXT condition, the S^D and S$^\Delta$ rates of both birds eventually moved towards convergence. During the last three sessions of this phase, the S^D/S$^\Delta$ response rates per minute produced by Birds B6 and B9 were: 54/58, 64/50, and 72/ 51 for B6; 46/46, 67/53, and 38/32 for B9. Several studies have reported differential response rates maintained on mixed reinforcement/extinction schedules (e.g., Bullock, 1960; Bullock & Smith, 1953; Perkins & Cacioppo,

1950; Porter & Neuringer, 1984; Raslear, Pier-rel-Sorrentino, & Brissey, 1975; Sadowsky, 1969; Weissman, 1960). The discrimination indices frequently do not stabilize at 50%, probably due to schedule cues (Jenkins, 1965). Furthermore, the differences between the S^D and S$^\Delta$ rates established with a multiple schedule have been reported to gradually, rather than suddenly, converge when a mixed schedule is introduced (Hirota, 1974).
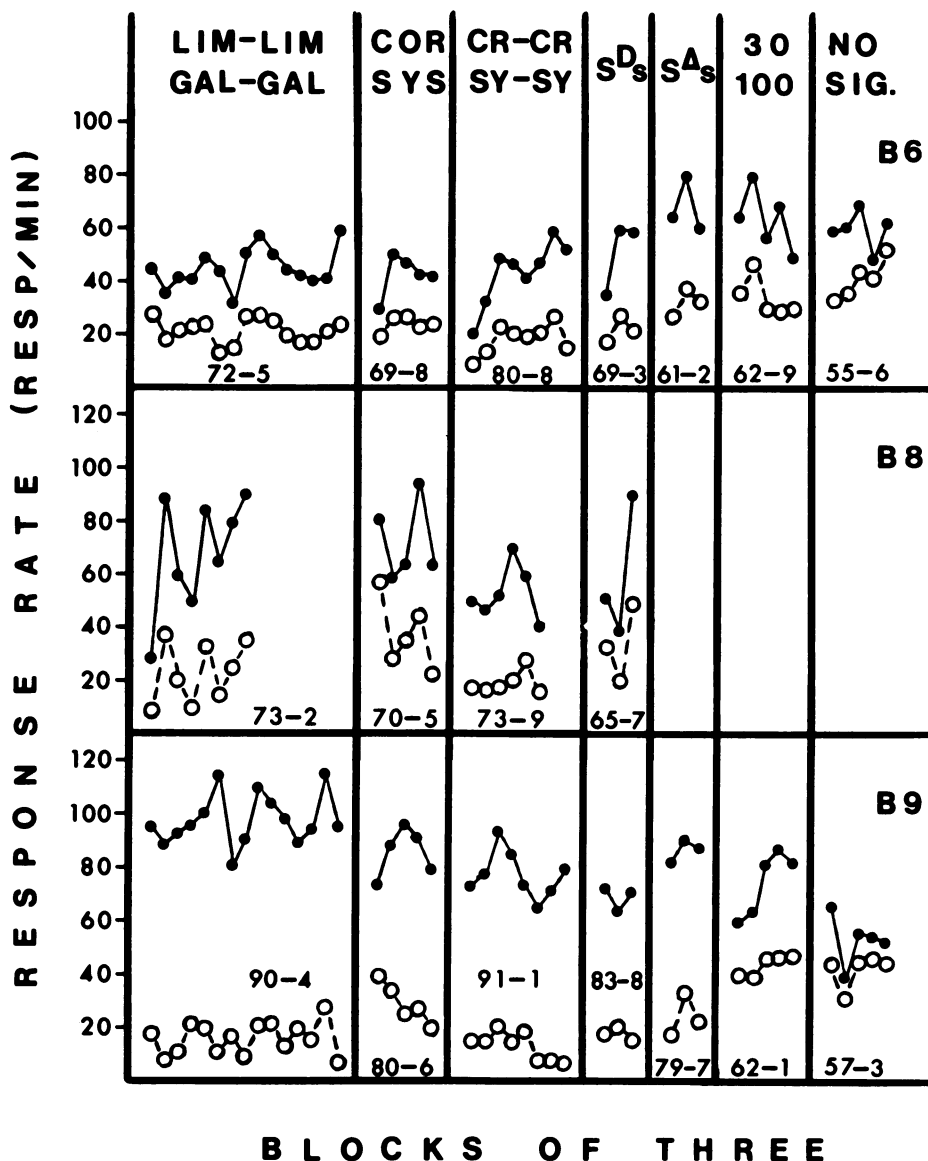
Fig. 6. Mean response rates during S^D (filled circles) and S^A (open circles) for successive 3-session blocks of sessions during each of the seven phases of Experiment 3. The mean discrimination index and its standard deviation, computed over the last five sessions of each condition, are indicated in the bottom of each panel.

GENERAL DISCUSSION

Earlier papers have reported that birds perform poorly on some auditory discrimination tasks (e.g., Guttman & Kalish, 1956; Mackintosh, 1974; Powell, 1973; Shettleworth, 1972). This poor discriminative performance is apparently not due to lack of auditory acuity. Audition in birds has been shown to be similar to that of mammals over some frequency ranges (Abs, 1983; Harrison & Furumoto, 1971; Stebbins, 1983). Beer (1970) showed that pigeons can discriminate between pigeon calls, and Pepperberg (1983) trained an African Grey parrot to discriminate between a large variety of objects via vocal labels. As cited earlier, D'Amato and Salmon (1982), Hulse et al. (1984), and Porter and Neuringer (1984) all reported complex auditory stimulus control.

Experiment 1 of the present study demonstrated that pigeons can learn to discriminate between word stimuli, and that the time between consecutive word presentations is influential. Intermittent presentation of the auditory stimuli may also have reduced the possibility of habituation and increased the likelihood that the birds would attend to the auditory cues (Pierrel & Blue, 1967). The fact that reinforcers could be produced only during the silent periods between S^D presentations makes the stimulus control exhibited more remarkable.

Experiment 2 showed that word length also contributed to control of the birds' performances. The data from Experiment 3 suggest that the birds initially responded to double-word occurrences as new words, but double-word stimuli eventually exerted more discriminative control than did single-word stimuli. Overall, the greatest differentiations were produced with the shortest interstimulus intervals and with the longest-duration auditory stimuli—that is, three-syllable words and double-word stimuli. The word length (stimulus duration) was 500 ms to 750 ms during the three-syllable and double-word conditions. Some of the lowest values of the discrimination index were produced during the first two phases with word stimuli (Experiment 1, Phases 4 and 5) and during the last two phases of Experiment 3. The word length ranged from 0 to 340 ms during those phases. In a related paper, Hulse et al. (1984) reported that longer-duration auditory stimuli resulted in better discrimination performances in experiments with European starlings.

The differences between the S^D and S^Δ rates were not statistically significant during the first few sessions of most phases of the experiments. However, the birds typically produced reliable differential response rates in 3 to 10 sessions of each new phase. Other researchers have also reported rapid acquisition of auditory discriminations. Sadowsky (1969) trained rats on a multiple VI 30-s EXT schedule in which different click rates functioned as the auditory cues. The discrimination indices for some of his subjects ranged between 62% and 68% during the first training session, and exceeded 80% after four sessions of training. Pierrel and Blue (1967) trained rats to discriminate between two different intensities of sound, with discrimination indices reaching 70% to 78% after 9 hr of training. In their recent paper, Porter and Neuringer (1984) reported that their birds began to respond differentially in the presence of two pieces of music within one to three sessions, and were producing index values of 75% to 90% within 12 sessions. Later, novel pieces of music were introduced and the birds showed facilitated acquisition. Our birds produced comparable results.

The data from the last phase of Experiment 3 (the mixed-schedule condition) indicate that although there was some evidence for direct control by the irregularly alternating 1-min components of extinction and the VI schedule, the slightly differential response rates did not hold up with continued exposure to the mixed schedule. Thus, the discriminative performances appear to have been controlled mainly by the words rather than by schedule artifacts. Some of the previously cited papers also conducted mixed-schedule conditions and reported similar results. Sadowsky (1969) trained one control group of rats on a mixed VI 30-s EXT schedule. Their discrimination index had a value of 48% during the first session of training but increased to 62% after 12 sessions. Porter and Neuringer (1984) presented their birds with a control session in which no auditory stimuli were provided. The discrimination indices for their birds were 55% and 62% during this mixed VI 30-s EXT schedule condition. Pierrel and Blue (1967) trained a control group on a mixed VI 60-s EXT schedule and reported discrimination indices ranging between 52% and 57%. During the first 9 hr of training, 1 animal showed a greater degree of discrimination on the mixed schedule than 3 of the 4 animals being trained on a multiple VI 60-s EXT schedule.

In a related experiment, Raslear et al. (1975) trained chinchillas on a three-component multiple schedule that employed auditory cues. They varied the intensity (and presumably the discriminability) of the tones. Their data suggest that the behavior of the animals was predominantly controlled by the auditory cues during initial training. When the auditory cues became more difficult to discriminate, or were absent during a mixed-schedule condition, responding became more directly controlled by features of the reinforcement schedule. Schedule cues probably contributed somewhat to the differential perfor-

mance of our birds, particularly during the first few sessions of phases that introduced new words and during the mixed-schedule condition. It would have been surprising if schedule cues exerted no influence after 500 sessions of training. However, it is unlikely that schedule cues alone were responsible for the highest values of the discrimination index obtained in the present experiments (i.e., B6, 82%; B7, 87%; B8, 85%; and B9, 91%).

If schedule cues alone were the primary controlling variable, we would have expected to observe fairly stable differential response rates throughout all phases, regardless of the auditory stimuli presented and regardless of most changes in procedure. For example, we would not have expected the rate differentials to increase when the time between stimulus presentations was reduced from 3 s to 1 s (Experiment 1, Phase 7), or to decrease when the ISI was again increased to 3 s (Experiment 2, Phase 6). Nor would the discrimination indices have been expected to decrease when letters instead of words were presented (Experiment 2, Phase 3), or during the mixed-schedule conditions of the last phase. Overall, a comparison of the discrimination indices obtained during the earlier phases with those obtained during the last phase suggests that the discriminations were based primarily on the words.

The present work suggests that spoken words, produced by electronic speech synthesizers capable of accurately repeating hundreds of words without variance, should be added to the list of discriminative stimuli available for research pursuits. Just as the in-line projector provided standardization of visual stimuli, the speech synthesizer provides a comparable function for auditory stimuli. More research employing complex stimuli and procedures is needed, permitting us to gain a whole sense modality, other than vision, in which to explore sensitivity of behavior to complex stimuli.

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