JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 2009, **92,** 199–214 NUMBER 2 (SEPTEMBER)

RESISTANCE TO CHANGE AND FREQUENCY OF RESPONSE-DEPENDENT STIMULI UNCORRELATED WITH REINFORCEMENT

Christopher A. Podlesnik, Corina Jimenez-Gomez, Ryan D. Ward, and Timothy A. Shahan

UTAH STATE UNIVERSITY

Stimuli uncorrelated with reinforcement have been shown to enhance response rates and resistance to disruption; however, the effects of different rates of stimulus presentations have not been assessed. In two experiments, we assessed the effects of adding different rates of response-dependent brief stimuli uncorrelated with primary reinforcement on relative response rates and resistance to change. In both experiments, pigeons responded on variable-interval 60-s schedules of food reinforcement in two components of a multiple schedule, and brief response-dependent keylight-color changes were added to one or both components. Although relative response rates were not systematically affected in either experiment, relative resistance to presession feeding and extinction were. In Experiment 1, adding stimuli on a variable-interval schedule to one component of a multiple schedule either at a low rate (1 per min) for one group or at a high rate (4 per min) for another group similarly increased resistance to disruption in the components with added stimuli. When high and low rates of stimuli were presented across components (i.e., within subjects) in Experiment 2, however, relative resistance to disruption was greater in the component presenting stimuli at a lower rate. These results suggest that stimuli uncorrelated with food reinforcement do not strengthen responding in the same way as primary reinforcers.

Key words: behavioral momentum theory, uncorrelated stimuli, conditioned reinforcement, response strength, resistance to change, key peck, pigeon

Stimuli signaling that important events are forthcoming have been shown to affect behavior in a number of ways. Neutral stimuli eventually come to elicit conditioned responses by their association with unconditioned stimuli (Pavlov, 1927; see Pearce & Bouton, 2001, Wasserman & Miller, 1997, for reviews). Conditioned stimuli presented contingent on behavior purportedly maintain responding through a process of conditioned reinforcement (see Williams, 1994, for a review). Contextual stimuli can modulate or ''set the occasion'' for the relation between conditioned and unconditioned stimuli (Holland, 1983) or between responses and primary reinforcers (Skinner, 1938). Regardless of the form and function of these stimuli, the value or impact these stimuli have on behavior comes from their relation in some way to unconditioned stimuli or primary reinforcement.

Reed and Doughty (2005) showed that stimuli seemingly unrelated to the presentation of food reinforcers also could exert effects on operant behavior. In their experiment, rats responded for food reinforcement on equal random-interval (RI) 60-s schedules in two components of a multiple schedule. In one of those components, a 0.5-s onset of white noise also was presented on a separate RI 60-s schedule. Reed and Doughty found that response rates were higher in the context with added white noise (see Donny et al., 2003; Neuringer & Chung, 1967; Stubbs, 1971, for related findings). Moreover, when responding was disrupted in both components by extinction, presession satiation, or presenting food response independently between components, responding was more resistant to disruption in the component presenting contingent white noise. According to behavioral momentum theory, differences in resistance to disruption are indicative of differences in underlying response strength (see Nevin & Grace, 2000, for a review). Therefore, in the context of behavioral momentum theory, the white noise enhanced the strength of responding in that

---

The authors would like to thank Wade Poulson for assistance in conducting these experiments and Mark Groskreutz and Nicky Groskreutz for many insightful discussions about these data. Thank you to Jack Smethells and Dennis Hand for providing a program for data analysis. CAP and CJ are now at the University of Michigan and RDW is now at Columbia University.

Address correspondence to: Christopher A. Podlesnik, Ph.D., Department of Pharmacology, University of Michigan Medical School, 1301 MSRB III, 1150 W Medical Center Dr., Ann Arbor, MI 48109-5632 (e-mail: cpod@umich.edu).

doi: 10.1901/jeab.2009.92-199

component compared to the component without white noise.

Behavioral momentum theory suggests that relative resistance to disruption is a function of the relative rate or magnitude of reinforcement across stimulus contexts (i.e., stimulus–reinforcer relation; Nevin & Grace, 2000). Consistent with this suggestion, relative resistance to disruption has been shown to be greater in stimulus contexts presenting higher rates or greater magnitudes of reinforcement (see Nevin, 1992, for a review). Reed and Doughty (2005) suggested that the added stimuli in their study could have functioned in a manner similar to primary reinforcement. Specifically, they suggested that adding the white noise on a RI 60-s schedule to a context presenting a RI 60-s schedule of food reinforcement might be analogous to simply presenting reinforcement at a higher rate (i.e., a RI 30-s schedule of reinforcement). Following this argument, if the added stimuli functioned as primary reinforcers, then the findings from Reed and Doughty would be analogous to those in which qualitatively different reinforcers added to a stimulus context increase relative resistance to disruption (Grimes & Shull, 2001; Shahan & Burke, 2004). If the added stimuli functioned as additional primary reinforcers (perhaps through a sensory reinforcement process; see Kish, 1966, for a review) and enhanced the stimulus–reinforcer relation in that context, the findings from Reed and Doughty would be consistent with a behavioral momentum framework.

Nonetheless, the finding that response-dependent presentations of stimuli uncorrelated with primary reinforcement can affect relative resistance to change is perplexing given that higher rates of stimuli correlated with primary reinforcement (i.e., conditioned reinforcers) have been shown not to impact relative resistance to change (Shahan & Podlesnik, 2005). Shahan and Podlesnik presented pigeons with a multiple schedule of observing-response procedures in which both components produced alternating periods of variable interval (VI) food reinforcement and extinction that were not differentially signaled (i.e., mixed schedules). Observing responses in both components changed the mixed schedules to multiple schedules (i.e., differentially signaled VI food reinforcement and extinction). Across components, the rate of differential stimulus presentation was either four- or six-fold across experiments, while the programmed rate of food delivery was equal across components. Overall, observing rates were higher when differential stimuli were presented at higher rates (see also Shahan, Podlesnik, & Jimenez-Gomez, 2006); however, relative resistance to disruption was not affected by rate of stimulus presentation. These findings suggest that, unlike different rates of primary reinforcement (e.g., Nevin, 1974), different rates of stimuli correlated with primary reinforcement do not impact relative response strength. Thus, the finding that stimuli uncorrelated with reinforcement can increase resistance to change is surprising.

The overall goal of the present experiments was to provide a better context for understanding the effects of uncorrelated response-dependent stimuli on relative resistance to disruption by examining whether higher rates of such stimuli produce greater resistance to change. Unlike the effects of different rates of primary reinforcers (e.g., Nevin, 1974) and stimuli correlated with primary reinforcers (Shahan & Podlesnik, 2005), the effects of different rates of response-dependent stimuli uncorrelated with primary reinforcement on relative response rates and relative resistance to change have yet to be examined. In Experiment 1, the effects of lower and higher rates of uncorrelated stimuli were first examined across groups with pigeons and keylight color changes to replicate and extend the findings of Reed and Doughty (2005). In addition, the results of Experiment 1 would allow for the effects of different rates of uncorrelated stimulus presentations to be assessed relative to a component without added stimuli. Next, the effects of different rates of uncorrelated stimuli were directly examined across two components of a multiple schedule in Experiment 2. If uncorrelated stimuli affect resistance to change in a manner analogous to primary reinforcers, responding in both experiments might be expected to be more resistant to change in contexts with higher rates of such stimuli.

EXPERIMENT 1

Two groups of pigeons responded on a two-component multiple schedule arranging VI

60-s schedules of food reinforcement in both components. For the first group, 0.5-s keylight color changes were arranged on a VI 60-s schedule in one component. Therefore, the rate of stimulus presentation occurred at the same rate as in Reed and Doughty (2005). The goal of using the first group in the present experiment was to replicate and assess the generality of the effects obtained by Reed and Doughty with a different species (pigeons instead of rats) and stimuli (visual instead of auditory). For the second group, 0.5-s keylight color changes were presented in one component on a VI 15-s schedule. Thus, the rate of keylight-color changes in that component was four times that for the first group. If the group that received a higher rate of stimulus presentation produced higher response rates and/or greater resistance to disruption than the group receiving a lower rate of stimulus presentation, the suggestion by Reed and Doughty that the stimuli had response-strengthening effects like primary reinforcers would be supported.

Method

Subjects

Four homing pigeons participated in each group. They were maintained at approximately 80% of their free-feeding weights (+/− 15 g) by postsession supplemental feeding of pelleted pigeon food as necessary. The pigeons had experience with multiple schedules of reinforcement similar to those used in the present experiment. Pigeons were housed in individual cages in a temperature-controlled room with a 12:12 hr light/dark cycle with lights on at 7:00 a.m. All pigeons had free access to water in their home cages.

Apparatus

Four sound-attenuating chambers were used. The chambers were clear plastic and aluminum measuring 29 cm long × 26 cm wide × 29 cm high. Each chamber had two response keys located 2 cm from the side walls and 16 cm above the floor. Response keys measured 2.5 cm in diameter and required a force of about 0.1 N to operate. Each keypeck produced a brief click as a result of the closing of the microswitch. The keys could be illuminated from behind with red, green, and white light via 28-V DC bulbs. A 28-V DC lamp centered above the key and 33 cm from the floor of the chamber served as a houselight. A 6-cm × 5-cm aperture directly centered below the response keys and 5 cm from the chamber floor allowed access to a solenoid-operated hopper filled with pigeon chow. During hopper presentations, the opening was lit with a white light, and the houselight and keylight were extinguished. A ventilation fan masked extraneous sounds. Control of experimental events and data recording were conducted with a microcomputer using Med Associates® interfacing and software.

Procedure

A two-component multiple schedule with equal rates of food reinforcement presented on VI 60-s schedules in each component was arranged. A VI schedule presenting 0.5-s keylight color changes was arranged in one component (hereafter VI+S component) but not in the other component (hereafter VI component). For the first group of pigeons, the keylight-color changes were presented on a VI 60-s schedule (hereafter Low Group). For the other group, the keylight-color changes were presented at a higher rate on a VI 15-s schedule (hereafter High Group). Technically, these were conjoint schedules because food and keylight-color changes were presented on separate schedules of reinforcement (see Imam & Lattal, 1992). All VI schedules were composed of 13 intervals (Fleshler & Hoffman, 1962) selected without replacement. The components assigned to the left and right keys were counterbalanced across pigeons with the brief stimulus, VI+S-component, and VI-component stimuli being green, red, and white, respectively, for Pigeons 39, 202, 218, and 220. The brief stimulus, VI+S-component, and VI-component stimuli were red, white, and green, respectively, for Pigeons 97, 217, 219, and 223.

The first component in each session was randomly chosen. The two components strictly alternated for the remainder of the session. All components were 60 s in duration and separated by a 20-s intercomponent interval (ICI) during which all keylights and the houselight were dark. If both a hopper presentation and a keylight-color change were concurrently available, the one that was arranged first would be presented. Following the termination of the hopper presentation or keylight-color change, the next available hopper or stimulus presentation would be presented contingent on the next response. Reinforcers scheduled but not obtained before the end of one component were held until the next occurrence of that component and were presented contingent on the first response. All hopper presentations were 2-s long and this time was excluded from the timing of all events. Sessions ended after each component was presented 20 times.

Baseline conditions continued until response rates were judged stable across at least six sessions, with the mean of the first three and last three sessions being within 10% of the mean of all six sessions (see Cumming & Schoenfeld, 1960). Following stability, relative resistance to change was tested using two amounts of presession feeding and two types of extinction. All disrupters were conducted for five consecutive sessions and each disruption condition was separated by at least six baseline sessions. All presession feeding took place 1 hr prior to experimental sessions. For the first presession feeding disruption (PF), subjects were fed 7.5% of their 80% free-feeding weight for three consecutive sessions and then 10% of their 80% free-feeding weight for an additional two consecutive sessions. Because disruption of responding tended to be small with this presession feeding regimen, a larger amount of presession feeding also was used. For the second presession feeding disruption (PF+), subjects were fed 12% of their 80% free-feeding weight for all five consecutive sessions.

During extinction, decreases in response rates have been shown to be a result of at least two separate processes—contingency termination and generalization decrement (see Nevin, McLean, & Grace, 2001). Assuming that removing keylight-color changes could be discriminated if removed during extinction (see Bell, Seip, & Fitzsimmons, 2007), resistance to extinction was assessed in two different ways. In one extinction type, only food presentations were discontinued while keylight-color changes continued to be presented in the VI+S component [EXT(s)]. In the other extinction type, all food presentations and keylight-color changes were discontinued in both components [EXT(ns)]. Experimental sessions were conducted 7 days a week at approximately the same time each day. Appendix 1 shows the number of baseline sessions during each condition prior to disruption, mean baseline response rates, response rates during individual sessions of disruption, and the order of disrupter presentation for both groups of pigeons.

An additional set of conditions also was examined in which the effects of directly pairing the brief stimuli in one component were examined, although the results from these conditions will not be presented in detail. Food and 0.5-s keylight-color changes were presented in both components on separate (i.e., conjoint) VI 60-s schedules. The only difference between components was that, in one component, a brief keylight-color change occurred during the first 0.5 s of every hopper (food) presentation. Thus, brief keylight-color changes were paired with food reinforcement in one component but not in the other. Resistance to disruption was assessed using presession feeding (12% of 80% free-feeding weight) and extinction with and without stimuli presented in both components.

RESULTS AND DISCUSSION

Food and stimulus presentations occurred at slightly lower rates than scheduled but were presented in proportions similar to those programmed. Food presentations per min were similar across components for the Low Group of pigeons (VI: Mean = 0.97, SD = 0.04; VI+S: Mean = 0.96, SD = 0.04) and for the High Group (VI: Mean = 0.95, SD = 0.03; VI+S: Mean = 0.97, SD = 0.05). Keylight-color changes occurred at similar rates as food presentations in the VI+S component for the Low Group (Mean = 0.94, SD = 0.04) but at a much higher rate for the High Group (Mean = 3.79, SD = 0.06).

Figure 1 shows response rates across successive baselines in the VI and VI+S components for individual pigeons and as group means in the Low and High Groups. Each data point for individual pigeons is the mean of six sessions prior to disruption. For both groups, response rates were higher in the VI+S component for 2 out of 4 pigeons. In the left column (Low Group), response rates were higher in the VI+S component for pigeons 39 and 97, but response rates were not systematically different across components for pigeons 202 and 217. In the right column (High Group), response rates were higher in the VI+S component for pigeons 219 and 220, but rates were not

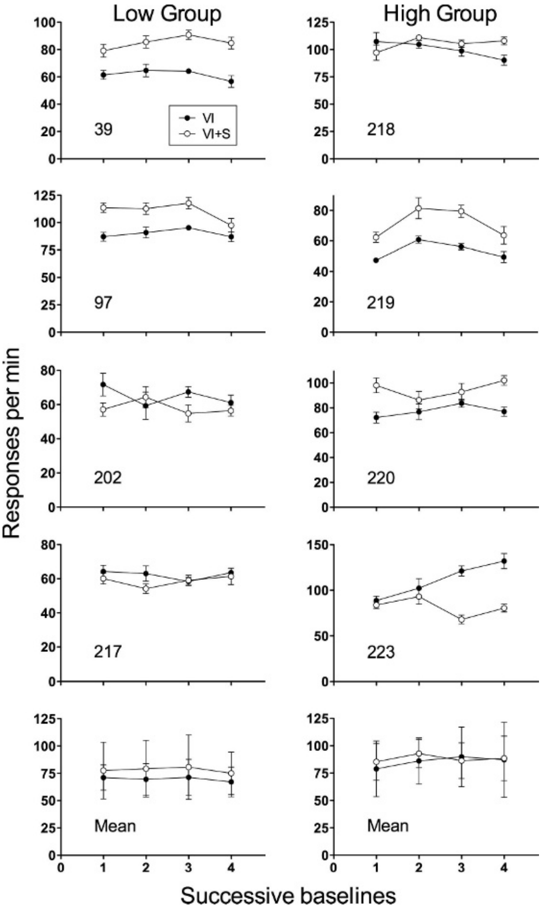

Fig. 1. Response rates in the VI and VI+S components across successive conditions of baseline in Experiment 1. The left panel shows response rates for the Low group (i.e., VI 60 s) and the right panel shows response rates for the High group (i.e., VI 15 s). Note that *y*-axes differ across pigeons. The mean across subjects for both groups is shown in the bottom row. Error bars indicate standard deviations.

systematically different across components for pigeon 218 and rates tended to be higher in the VI component for pigeon 223. In addition, there were no systematic differences across groups. Group differences in response rates were examined by comparing the difference in baseline response rates between the components (i.e., VI component – VI+S component) using a 2 × 4 mixed ANOVA with group as the between-subject factor and successive baseline as the within-subject factor. An alpha of 0.05 was used for all statistical tests. There were no significant differences between groups, $F(1,18) = 0.17$, $p = .70$, successive baseline $F(3,18) = 0.26$, $p = .85$, or for the interaction, $F(3,18) = 0.38$, $p = .77$. Thus, adding keylight-color changes did not systematically increase response rates (cf. Reed & Doughty, 2005), regardless of whether keylight-color changes were added on a VI 60-s schedule or at a higher rate on a VI 15-s schedule.

The effects of adding keylight-color changes on relative resistance to disruption, however, were more systematic. Figure 2 shows resistance to disruption in the VI component (black bars) and VI+S component (white bars) for the Low Group of pigeons in the left column and the High Group in the right column, separated by disrupter. Resistance to disruption is shown as the logarithm (log) of the mean proportion of baseline response rates (mean of six sessions) from all five sessions of disruption in both components. In addition, gray bars reflect relative effects by showing the difference in log proportion of baseline between those components (i.e., VI component – VI+S component). Thus, negative values indicate greater resistance to disruption in the VI+S component. Although the differences between components were not large, responding was more resistant to disruption in the VI+S component in 15 out of 16 instances for both the Low Group and the High Group. The exceptions are from the EXT(ns) disrupter for pigeon 217 in the Low Group and for pigeon 220 in the High Group.

These exceptions correspond to 2 out of 4 pigeons in the Low Group (Pigeons 97 and 217) and 3 out of 4 pigeons in the High Group (Pigeons 218, 219 and 220) for which disruption in the VI+S component increased relative to the VI component in the EXT(ns) disrupter compared to the EXT(s) disrupter. Although by no means conclusive, this pattern suggests the change in stimulus context during extinction was greater for some pigeons in the VI+S components than in the VI components during the EXT(ns) disrupter. Thus, the effect of removing the stimuli during extinction was less effective than the effect of adding uncorrelated stimuli on resistance to extinction in general.

Figure 3 shows mean resistance to all disrupter types across pigeons for both groups. Although responding was more resistant to disruption in the VI+S component for both groups, there was no difference in relative resistance to disruption between groups. The

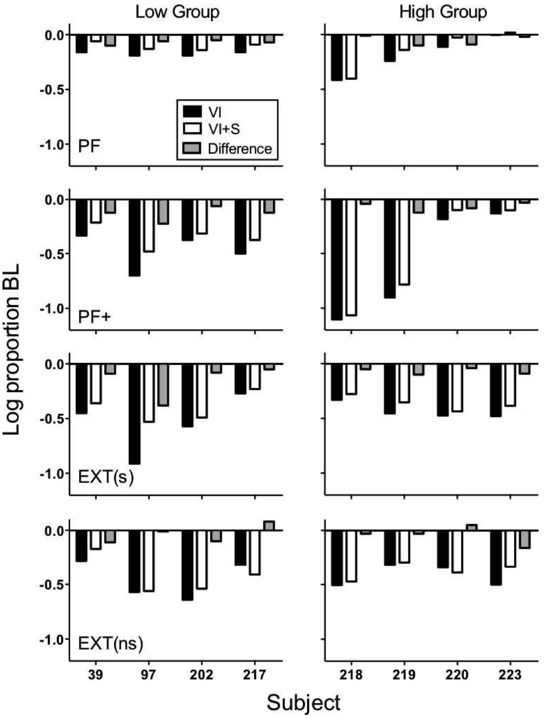

Fig. 2. Relative resistance to change for individual subjects across components in Experiment 1. Log mean proportion of baseline response rates in the VI and VI+S components for the Low group (i.e., VI 60 s) are shown in the left column and the High group (i.e., VI 15 s) are shown in the right column. Gray bars show the difference in log proportion of baseline response rates between the VI and VI+S components.

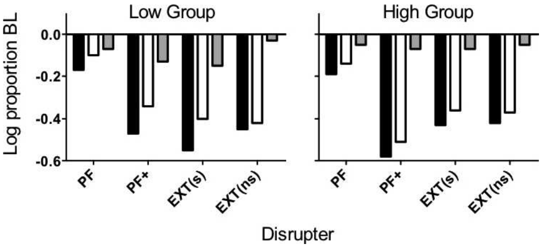

Fig. 3. Mean relative resistance to change across components in Experiment 1. The mean across subjects' log mean proportion of baseline response rates in the VI components (black bars) and VI+S components (white bars) are shown for the Low group (i.e., VI 60 s) on the left and the High group (i.e., VI 15 s) are shown on the right. Gray bars show the mean of individual-subject differences in log proportion of baseline response rates between the VI and VI+S components.

difference of log proportion of baseline response rates in the VI and VI+S components was compared using a 2 × 4 mixed ANOVA with group as the between-subjects factor and disrupter type as the within-subject factor. There were no significant differences between groups, $F(1,18) = 1.72$, $p = .24$, disrupter type, $F(3,18) = 1.56$, $p = .23$, or with the interaction, $F(3,18) = 0.99$, $p = .42$.

One potential way to account for greater resistance to disruption in the VI+S component in both groups is that the stimuli functioned as conditioned reinforcers. Several points argue against this interpretation. First, the stimuli were never directly paired with food reinforcement. In the best possible case for a pairing between stimuli and food, at least one response always occurred between a keylight-color change and food presentation. All other occurrences of stimuli and food were separated by multiple responses, additional stimuli or food, and/or component changes. The total number of stimuli and food presentations separated by only one response was low in both groups but, as one would expect, greater in the High group (Mean = 9.00, SEM = 0.71) than in the Low group (Mean = 1.75, SEM = 0.75). However, the percentage of total stimulus presentations that were followed by a single response prior to a food presentation also was low but similar between the groups (Low: Mean = 1.53%, SEM = 0.69%; High: Mean = 1.94%, SEM = 0.16%) and not statistically different according to an unpaired *t* test, $t(6) = 0.58$, $p = .58$. This general pattern does not change when two or three intervening responses are considered. If this low but similar percentage of stimuli with one intervening response was sufficient to imbue the stimuli with conditioned-reinforcing effects that were similar in both groups, then conditioned-reinforcing effects of those stimuli perhaps could explain the greater resistance to disruption in the VI+S component in both groups.

Second, if the brief stimuli became associated with food reinforcement and functioned as conditioned reinforcers, response rates might increase immediately following stimulus presentations, as indicated by shorter interresponse times (IRTs). Figure 4 shows the median of all four IRTs prior to and after all keylight-color changes and food presentations during the six-session baseline prior to the PF condition in both groups. Only stimuli and food presentations were included in the analysis if they had at least four IRTs prior to and after those events (to examine whether any trends existed across IRTs). First, it should be noted that the last IRT prior to both stimuli and food reinforcement tended to increase in most pigeons. This is consistent with the idea that VI schedules differentially reinforce longer IRTs (e.g., Shimp, 1969). Following stimuli, IRTs generally did not decrease compared to the first three IRTs prior to stimuli, with the exception of a decrease in the first poststimulus IRT for Pigeon 202 in the Low group. Conversely, clear decreases in IRTs occurred following food reinforcement for Pigeons 202 and 217 in the Low group and all pigeons in the High group. Thus, the brief keylight-color changes did not increase response rates reliably following their presentation, as might be expected if those stimuli functioned as conditioned reinforcers.

The final piece of evidence arguing against a conditioned-reinforcing interpretation of the stimuli comes from an additional experiment conducted with the same pigeons to more directly assess the effects of directly pairing brief stimuli with food reinforcement (see Procedure section). Brief keylight-color changes and food were presented on separate but equal VI 60-s schedules in two multiple-schedule components. In only one component were the stimuli simultaneously paired with food reinforcement. As in Experiment 1, relative response rates were not differentially affected across the paired and unpaired components. However, in contrast to Experiment 1, relative resistance to change was not systematically affected. Given that directly pairing brief stimuli with food reinforcement affected neither response rates nor resistance to change, these data suggest that the increased resistance to disruption in Experiment 1 with stimuli presented on a separate VI schedule did not necessarily result from the relatively few incidental pairings between stimuli and food.

It is unclear to what extent the stimuli in Reed and Doughty (2005) might have functioned as conditioned reinforcers because no local IRT analyses were conducted. In contrast to the present experiment, in which added stimuli had no systematic effect on relative baseline response rates, they found that adding 0.5-s presentations of white noise contingent on rats' lever pressing reliably increased response rates in a component presenting food relative to a component that presented food alone. Thus, the overall higher response rates in the component with added stimuli might have been a result of conditioned-reinforcing effects, with local increases in response rates following the stimuli. It also is possible that the different effects of added stimuli on response rates across these experiments could be a result of a number of other factors, including the differences in species, stimuli, or response type, among others (see Mazur, 2005, 2007).

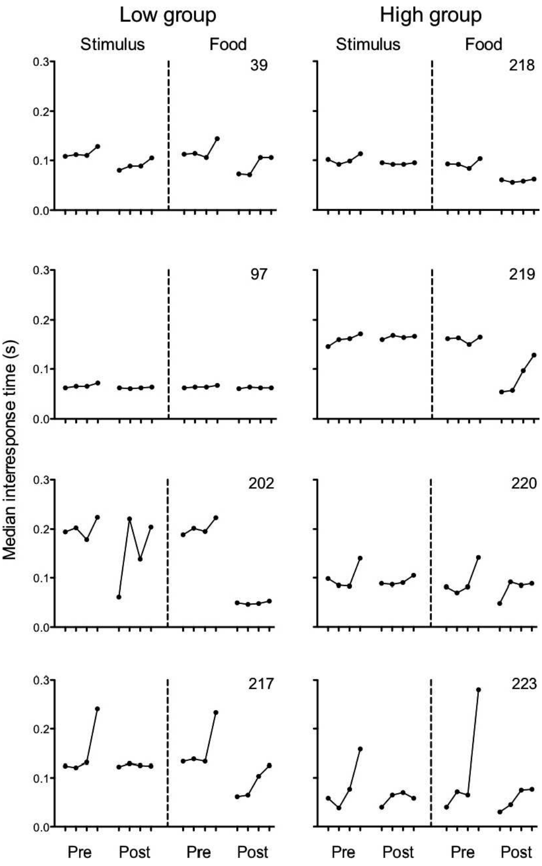

Fig. 4. Median IRTs (s) for the first four prestimulus, poststimulus, prefood, and postfood IRTs from the VI+S component for individual pigeons in the Low group and High group in Experiment 1. Across pigeons, 52% to 59% of stimuli and 53% to 65% of food presentations met the inclusion criterion (see text) in the Low group and 20% to 39% of stimuli and 36% to 51% of food presentations met this criterion in the High group.

Regardless of the unsystematic effects on response rates, relative resistance to disruption consistently was greater in the components presenting keylight-color changes, consistent with the findings of Reed and Doughty (2005). However, no clear differences in relative resistance to disruption were found as a function of the different rates of stimuli presented between the two groups in the present experiment. Experiment 2 examined the effects of different rates of stimulus presentation on response rates and resistance to change within subjects.

EXPERIMENT 2

Relative resistance to disruption was greater in components with added uncorrelated stimuli but was not systematically affected when different rates of stimuli were presented across groups of pigeons in Experiment 1. It is possible that the between-group assessments used in Experiment 1 were not sensitive enough to reveal any differential effects of presenting stimuli at different rates. For instance, Cohen (1998) showed that within-session alternations of stimulus contexts were necessary to detect reliable differences in relative resistance to disruption with different relative reinforcer rates across those contexts. Based on Cohen's findings, it might be necessary to present the different rates of keylight-color changes within the same session to detect any differential effects of rate of stimulus presentation. In addition, the findings from Experiment 1 cannot easily be compared to other studies of resistance to change in which responding was maintained by different rates of primary (e.g., Nevin, 1974) or conditioned (Shahan & Podlesnik, 2005) reinforcement because those studies arranged within-subject designs. Therefore, Experiment 2 examined whether different rates of keylight-color changes (i.e., those presented across groups in Experiment 1) differentially impact relative response rates and/or resistance to disruption when arranged across two components of a multiple schedule (i.e., a within-subject design).

Method

Subjects and Apparatus

Four homing pigeons participated in the experiment. They were the same as those from the Low Group of Experiment 1 and were maintained and housed in the same way as in Experiment 1. The experimental chambers were the same as those used in Experiment 1.

Procedure

The procedures were similar to those in Experiment 1, except where noted. A two-component multiple schedule arranged food on VI 60-s schedules of reinforcement in both components. In one component, 0.5-s keylight-color changes were presented on a separate VI 60-s schedule (hereafter the Low component). In the other component, 0.5-s keylight-color changes were presented on a separate VI 15-s schedule (hereafter the High component). The components assigned to the left and right keys were counterbalanced across pigeons. The brief stimulus, Low-component, and High-component stimuli were green, red, and white, respectively, for Pigeons 39 and 202 and red, white, and green, respectively, for Pigeons 97 and 217.

Following stability as described for Experiment 1, resistance to disruption was assessed for five consecutive sessions. Presession feeding (PF) was the same as in Experiment 1 (i.e., 12% of 80% free-feeding weight). Two types of extinction, similar to those from Experiment 1 but occurring in both components, were assessed. In one type, food presentations were discontinued in both components while keylight-color changes continued to occur in both components at the same rate of presentation as in baseline [EXT(s)]. In the other type of extinction, both food presentations and keylight-color changes were discontinued in the two components [EXT(ns)]. Appendix 2 shows the number of baseline sessions during each condition prior to disruption, mean baseline response rates, response rates during individual sessions of disruption, and the order of disrupter presentation.

Results and Discussion

Food presentations per min were similar across components (Low: Mean = 0.94, SD = 0.08; High: Mean = 0.94, SD = 0.05). Keylight-color changes occurred at a lower rate in the Low component compared to in the High component (Low: Mean = 0.94, SD = 0.04; High: Mean = 3.75, SD = 0.07). Figure 5 shows response rates across successive baselines in the Low and High components for all pigeons. Response rates were higher in the

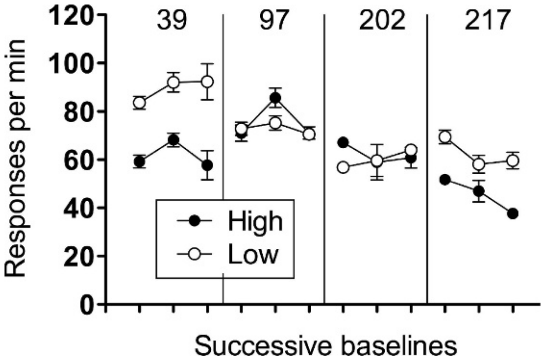

Fig. 5. Response rates in the Low and High components across successive conditions of baseline in Experiment 2. Error bars indicate standard deviations.

Low component for 2 out of 4 pigeons (39 and 217) and similar across components for the other 2 pigeons (97 and 202). Thus, rate of key-color change did not systematically impact baseline response rates.

Figure 6 shows relative resistance to disruption across the Low and High components (black and white bars, respectively) as log proportion of baseline response rates and the difference in resistance to disruption between the Low and High components (gray bars). Overall, responding tended to be more resistant to disruption in the Low component (10 out of 12 instances). The exception was with presession feeding for pigeons 202 and 217. Thus, lower rates of keylight color changes resulted in greater resistance to extinction and unsystematic differences in resistance to presession feeding. Comparing resistance to the EXT(s) and EXT(ns) disrupters, relative resistance to disruption between the Low and High components was (slightly) greater during EXT(s) for all 4 pigeons. These findings suggest that removing the keylight-color changes from both components with EXT(ns) might have reduced control by the discriminative stimuli to some extent during extinction.

Given that relative resistance to disruption was inversely related to rate of stimulus presentation in the present experiment, it is even more difficult to explain the effects of the stimuli with a conditioned-reinforcing account. If anything, higher rates of conditioned reinforcement might be expected to produce greater resistance to disruption. Consistent with the findings from Experiment 1, Figure 7 shows that decreases in IRTs (increased response rates) were not consistent following stimulus presentations in either component, with the exception of Pigeon 217. Following food presentations, however, decreases in IRTs were more common. In addition, similar to between groups in Experiment 1, there were more stimuli separated from food by only one response in the High component (Mean = 10.00, SEM = 2.04) than in the Low component (Mean = 2.75, SEM = 0.48), but the percentage across components was similar (High: Mean = 2.15%, SEM = 0.43%; Low: Mean = 2.35%, SEM = 0.38%). Thus, if anything, relative resistance to disruption might have been decreased by a greater absolute number of stimuli occurring close to food presentations in the High component.

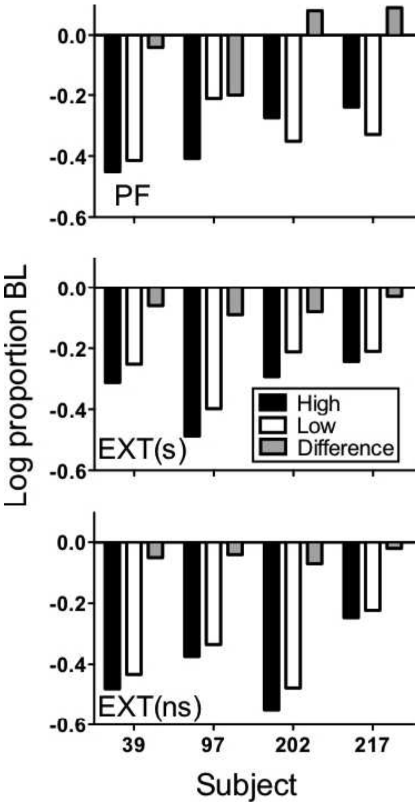

Fig. 6. Relative resistance to change across the Low and High components in Experiment 2. Gray bars show the difference in log proportion of baseline response rates between the Low and High components.

Overall, other than the two deviations during presession feeding, relative resistance to change tended to decrease with the higher rate of uncorrelated stimulus presentations.

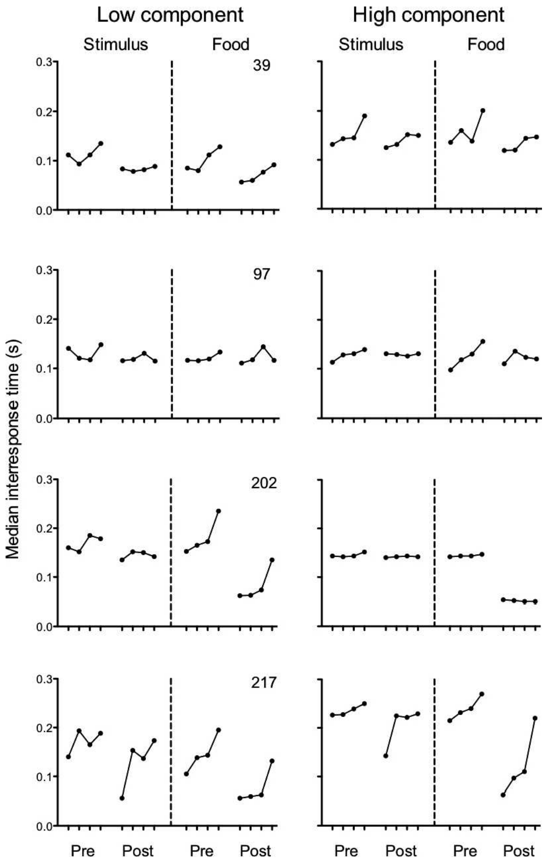

Fig. 7. Median IRT (s) for the first four prestimulus, poststimulus, prefood, and postfood IRTs from individual pigeons in the Low and High components in Experiment 2. Across pigeons, 20% to 56% of stimuli and 46% to 61% of food presentations met the inclusion criterion (see text) in the Low component and 30% to 41% of stimuli and 23% to 42% of food presentations met this criterion in the High component.

Therefore, arranging different rates of stimuli using a within-subject design produced differences in relative resistance to change that were not apparent when arranged between groups in Experiment 1 (see Cohen, 1998, for related findings). Along with the findings from Experiment 1, these findings further suggest that adding stimuli uncorrelated with primary reinforcement is not functionally equivalent to adding higher rates of primary reinforcement (see Reed & Doughty, 2005).

GENERAL DISCUSSION

The present experiments examined the effects of adding response-dependent stimulus changes uncorrelated with food reinforcement on relative response rates and relative resistance to change. In Experiment 1, resistance to disruption was greater in components with added stimulus changes than in components without stimulus changes, but different rates of added stimuli across groups had no differential impact. In Experiment 2, when different rates of stimuli were presented across components (i.e., within subjects), resistance to disruption was lower in the component presenting higher rates of stimuli. Relative response rates were not systematically affected in either experiment. These findings with added uncorrelated stimuli are at odds with general findings that higher rates of primary reinforcers (e.g., food, drugs) typically result in greater rates of responding (see Herrnstein, 1970) and greater relative resistance to disruption (see Nevin, 1992). Therefore, the present findings are not consistent with the hypothesis offered by Reed and Doughty (2005) that adding uncorrelated stimuli to a component might affect response rates and resistance to change in a manner similar to presenting a higher rate of primary reinforcement.

The finding that baseline response rates were not systematically affected in the present experiments is inconsistent with the effects of different rates of stimuli correlated with reinforcement, which have been shown to be positively related to response rates (e.g., Shahan & Podlesnik, 2005). However, several related studies examining effects of uncorrelated auditory stimuli with rats by Reed and colleagues (e.g., Reed & Doughty, 2005; Reed & Yoshino, 2008) suggest that the effects of uncorrelated stimuli on response rates are complex and vary with qualitative and quantitative aspects of the stimuli and experimental procedure. For instance, in concurrent VI VI schedules of food reinforcement, adding response-dependent clicks and longer tones (3 s) to one option increased responding on that option, but shorter tones (0.5 s) decreased responding on that option. These response-rate decreasing effects of shorter tones were attenuated when overall reinforcement rates were lower. Short 0.5-s bursts of white noise, on the other hand, increased response rates and resistance to disruption in a multiple schedule (Reed & Doughty, 2005). Given the variable effects of auditory stimuli with rats, it is possible that effects of visual stimuli in pigeons as used in the present experiment also could vary depending on the quantitative and qualitative nature of those stimuli. Although the present findings clearly suggest that uncorrelated stimuli do not function like primary or conditioned reinforcers, they do not provide a complete picture of those effects. To provide a more complete picture, the effects and interactions of dimensions of primary reinforcement (e.g., magnitude, duration, type) that have been shown to impact operant behavior, should be assessed parametrically with uncorrelated stimuli.

Unlike relative response rates, relative resistance to change was systematically impacted in Experiments 1 and 2. The effects of the stimuli on relative resistance to change, however, might be difficult to explain from the perspective of behavioral momentum theory. Behavioral momentum theory states that events that increase resistance to disruption do so by impacting response strength (see Nevin & Grace, 2000). If uncorrelated stimuli enhance response strength, higher rates of those stimuli should increase resistance to change. Instead, when compared to a component with no added stimuli, higher rates of uncorrelated stimuli did not enhance relative resistance to change compared to when lower rates were presented (Experiment 1). Furthermore, when different rates of stimuli were presented in two components (Experiment 2), higher rates of stimuli decreased relative resistance to change. Therefore, the uncorrelated stimuli influenced resistance to disruption but did not follow a pattern consistent with a response-strengthening account. For this reason, it is unclear how to incorporate the present findings into the framework of behavioral momentum theory.

Explanations of the present resistance to change findings from a conditioned-reinforcing perspective also are difficult. If the stimuli functioned as conditioned reinforcers, relative response rates and relative resistance to change should have been positively related to rate of stimulus presentation in Experiments 1 and 2. In addition, local analysis of IRTs from Experiments 1 and 2 did not reveal increases in local response rates following stimuli even though food presentations did increase local response rates. Finally, neither response rates nor resistance to change were differentially impacted in the study briefly reported with Experiment 1 in which stimuli were differentially paired with food reinforcement across multiple-schedule components.

These points of evidence, however, cannot completely rule out the possibility that the stimuli functioned as conditioned reinforcers. For instance, one particular feature of the uncorrelated stimuli used in the present experiments that might have influenced responding is that keylight illumination changed abruptly both during uncorrelated stimuli (color change) and with food reinforcement (keylight turned off). Thus, the keylight-color changes might have had conditioned-reinforcing effects due to an overlap in stimulus features, and the inverse relation between stimulus rate and relative resistance to change could then be a result of the stimuli being presented repeatedly in the absence of food reinforcement. That is, each stimulus presentation might have resulted in a ‘‘frustration’’ effect similar to that described by Amsel (1962). The extent to which different rates of stimuli produce such effects could explain the inverse relation between stimulus rate and resistance to disruption in Experiment 2.

The finding that the stimuli had different effects between Experiments 1 and 2 might be due to the fact that stimuli can play multiple roles depending on the context. For example, Reed and Hall (1989) found that brief auditory stimuli presented midway through a variable-ratio (VR) 30 (or 200) schedule of food reinforcement with rats enhanced responding by producing a pattern of lever pressing identical to that of responding on a richer VR 15 (or 100) schedule. Reed and Hall suggested the stimuli in their experiments improved discrimination of the operant schedule and therefore learning about the functional unit of responding (see Neuringer & Chung, 1967; Stubbs, 1971, for related discussions). Another effect of the stimuli in Reed and Hall’s study occurred because those stimuli always were presented in the middle of the VR 30 schedule—the stimuli were never paired with food. As a result, the stimuli displayed conditioned-inhibitory properties, as indicated by superconditioning to a novel light stimulus when compounded with the previous brief auditory stimulus. Perhaps the stimuli in the present experiments functioned in a similar manner as those in Reed and Hall’s study. Specifically, the stimuli enhanced resistance to disruption in Experiment 1, perhaps by improving discrimination of the operant schedule, when different rates of stimuli were compared indirectly across groups. However, when tested under a different set of conditions in Experiment 2, in which the effects of the stimuli were directly compared within subjects, the stimuli might have differentially impacted relative resistance to disruption through different levels of inhibitory conditioning to the stimuli across components.

Regardless of the mechanism underlying the findings of the present experiments, these findings suggest a complex relation between stimuli and primary reinforcement. Like the effects of different rates of uncorrelated stimuli in the present experiments, Shahan and Podlesnik (2005) found either an inverse or no relation between stimulus rate and resistance to change when observing responses produced stimuli explicitly correlated with primary reinforcement (see Shahan & Podlesnik, 2008, for a review). In those studies, however, small differences in rate of primary reinforcement across components in the contexts in which observing occurred could explain the absent or inverse relations between stimulus rate and resistance to change. Importantly, there were no differences in primary reinforcement rate across components in the present experiments. Therefore, to fully understand the relation between stimuli and primary reinforcement in general, additional experiments comparing the effects of stimuli correlated and uncorrelated with primary reinforcement on operant behavior are needed.

REFERENCES

Amsel, A. (1962). Frustrative nonreward in partial reinforcement and discrimination: Some recent history and theoretical extension. *Psychological Review, 69*, 306–328.

Bell, M. C., Seip, K. M., & Fitzsimmons, K. S. (2007). Effect of signaling reinforcement on resistance to change in a multiple schedule. *Behavioural Processes, 74*, 33–48.

Cohen, S. L. (1998). Behavioral momentum: The effects of the temporal separation of rates of reinforcement. *Journal of the Experimental Analysis of Behavior, 69*, 29–47.

Cumming, W. W., & Schoenfeld, W. N. (1960). Behavior stability under extended exposure to a time-correlated reinforcement contingency. *Journal of the Experimental Analysis of Behavior, 3*, 71–82.

Donny, E. C., Chaudhri, N., Caggiula, A. R., Evans-Martin, F. F., Booth, S., Gharib, M. A., et al. (2003). Operant responding for a visual reinforcer in rats is enhanced by noncontingent nicotine: Implications for nicotine self-administration and reinforcement. *Psychopharmacology, 169*, 68–76.

Fleshler, M., & Hoffman, H. S. (1962). A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior, 5*, 529–530.

Grimes, J. A., & Shull, R. L. (2001). Response-independent milk delivery enhances persistence of pellet-reinforced lever pressing by rats. *Journal of the Experimental Analysis of Behavior, 76*, 179–194.

Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior, 13*, 243–266.

Holland, P. C. (1983). Occasion-setting in Pavlovian feature positive discriminations. In M. L. Commons, R. J. Herrnstein, & A. R. Wagner (Eds.), *Quantitative analyses of behavior: Discrimination processes* (Vol. 4, pp. 183–206). New York: Ballinger.

Imam, A. A., & Lattal, K. A. (1992). A suggestion for describing combinations of response-dependent and response-independent events. *The Behavior Analyst, 15*, 179–182.

Kish, G. B. (1966). Studies of sensory reinforcement. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 109–159). *New York: Appleton-Century-Crofts.*

Mazur, J. E. (2005). Effects of reinforcer probability, delay, and response requirements on the choices of rats and pigeons: Possible species differences. *Journal of the Experimental Analysis of Behavior, 83*, 263–279.

Mazur, J. E. (2007). Species differences between rats and pigeons in choices with probabilistic and delayed reinforcers. *Behavioural Processes, 75*, 220–224.

Neuringer, A. J., & Chung, S-H. (1967). Quasi-reinforcement: Control of responding by a percentage-reinforcement schedule. *Journal of the Experimental Analysis of Behavior, 10*, 45–54.

Nevin, J. A. (1974). Response strength in multiple schedules. *Journal of the Experimental Analysis of Behavior, 21*, 389–408.

Nevin, J. A. (1992). An integrative model for the study of behavioral momentum. *Journal of the Experimental Analysis of Behavior, 57*, 301–316.

Nevin, J. A., & Grace, R. C. (2000). Behavioral momentum and the Law of Effect. *Behavioral and Brain Sciences, 23*, 73–130.

Nevin, J. A., McLean, A. P., & Grace, R. C. (2001). Resistance to extinction: Contingency termination and generalization decrement. *Animal Learning & Behavior, 29*, 176–191.

Pavlov, I. P. (1927). *Conditioned reflexes.* London: Routledge and Kegan Paul.

Pearce, J. M., & Bouton, M. E. (2001). Theories of associative learning in animals. *Annual Review of Psychology, 52*, 111–139.

Reed, P., & Doughty, A. H. (2005). Within-subject testing of the signaled-reinforcement effect on operant responding as measured by response rate and resistance to change. *Journal of the Experimental Analysis of Behavior, 83*, 31–45.

Reed, P., & Hall, G. (1989). The quasi-reinforcement effect: The influence of brief stimuli uncorrelated with reinforcement on variable ratio schedules. *Learning & Motivation, 20*, 242–261.

Reed, P., & Yoshino, T. (2008). Effect of contingent auditory stimuli on concurrent schedule performance: An alternative punisher to electric shock. *Behavioural Processes, 78*, 421–428.

Shahan, T. A., & Burke, K. A. (2004). Ethanol-maintained responding of rats is more resistant to change in a context with added non-drug reinforcement. *Behavioral Pharmacology*, *15*, 279–285.

Shahan, T. A., & Podlesnik, C. A. (2005). Rate of conditioned reinforcement affects observing rate but not resistance to change. *Journal of the Experimental Analysis of Behavior*, *84*, 1–17.

Shahan, T. A., & Podlesnik, C. A. (2008). Quantitative analyses of observing and attending. *Behavioural Processes*, *78*, 145–157.

Shahan, T. A., Podlesnik, C. A., & Jimenez-Gomez, C. (2006). Matching and conditioned reinforcement rate. *Journal of the Experimental Analysis of Behavior*, *85*, 167–180.

Shimp, C. P. (1969). The concurrent reinforcement of two interresponse times: The relative frequency of an interresponse time equals its relative harmonic length. *Journal of the Experimental Analysis of Behavior*, *12*, 403–411.

Skinner, B. F. (1938). *The behavior of organisms: An experimental analysis*. Cambridge, MA: Appleton-Century-Crofts.

Stubbs, D. A. (1971). Second-order schedules and the problem of conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, *16*, 289–313.

Wasserman, E. A., & Miller, R. R. (1997). What's elementary about associative learning? *Annual Review of Psychology*, *48*, 573–607.

Williams, B. A. (1994). Conditioned reinforcement: Neglected or outmoded explanatory construct? *Psychonomic Bulletin & Review*, *1*, 457–475.

Received: March 24, 2009
Final Acceptance: June 10, 2009

APPENDIX 1

Mean responses per min from successive baselines (BL) and individual sessions of disruption in the VI and VI+S components. Conditions are presented in the order they occurred with the number of sessions per condition. Disrupters included presession feeding (PF), large-amount presession feeding (PF+), extinction with stimuli [EXT(s)], and extinction with no stimuli [EXT(ns)] for individual pigeons from the Low and High groups. Response-rate standard deviations are presented in italics.

Low group					High group				
			Component					Component	
Pigeon	Condition	Sessions	VI	VI+S	Pigeon	Condition	Sessions	VI	VI+S
39	PF BL	31	61.49	79.13	218	PF BL	36	107.30	97.18
			3.26	*4.62*				*8.25*	*6.89*
	PF	1	46.45	70.75		PF	1	101.70	80.15
	PF	1	43.45	66.70		PF	1	86.30	78.95
	PF	1	32.60	68.20		PF	1	17.55	26.90
	PF	1	44.60	68.55		PF	1	0.00	3.20
	PF	1	46.90	69.20		PF	1	1.15	3.20
	PF+BL	21	64.71	85.52		PF+BL	8	104.73	110.95
			4.55	*4.42*				*3.64*	*2.09*
	PF+	1	47.90	60.80		PF+	1	40.95	47.55
	PF+	1	17.25	50.7		PF+	1	0.40	0.05
	PF+	1	14.05	35.15		PF+	1	0.00	0.05
	PF+	1	36.40	58.85		PF+	1	0.00	0.00
	PF+	1	37.25	58.55		PF+	1	0.00	0.10
	EXT (ns) BL	7	64.21	90.79		EXT (ns) BL	8	98.77	105.40
			1.90	*3.45*				*4.88*	*3.30*
	EXT (ns)	1	61.30	90.00		EXT (ns)	1	76.80	78.40
	EXT (ns)	1	42.20	75.60		EXT (ns)	1	23.80	28.70
	EXT (ns)	1	24.55	48.55		EXT (ns)	1	26.10	32.70
	EXT (ns)	1	23.05	51.55		EXT (ns)	1	13.25	18.35
	EXT (ns)	1	18.75	40.45		EXT (ns)	1	14.60	19.50
	EXT (s) BL	6	56.69	84.78		EXT (s) BL	7	90.29	107.99
			4.29	*4.33*				*4.63*	*3.67*
	EXT (s)	1	29.55	52.60		EXT (s)	1	84.70	110.00
	EXT (s)	1	23.95	49.75		EXT (s)	1	63.60	79.25
	EXT (s)	1	28.75	45.75		EXT (s)	1	35.20	41.60
	EXT (s)	1	7.90	18.25		EXT (s)	1	18.00	32.90
	EXT (s)	1	10.75	20.00		EXT (s)	1	9.65	21.20
97	PF BL	30	87.11	113.63	219	PF BL	32	47.37	62.31
			4.00	*4.38*				*1.75*	*3.32*
	PF	1	85.10	115.10		PF	1	35.60	52.95
	PF	1	97.15	118.70		PF	1	34.95	58.85
	PF	1	43.65	68.95		PF	1	28.90	49.20
	PF	1	18.25	56.30		PF	1	17.55	28.25
	PF	1	36.50	63.35		PF	1	19.20	36.40
	PF+BL	15	90.93	112.78		PF+BL	12	60.78	81.43
			4.93	*5.29*				*2.30*	*6.87*
	PF+	1	22.25	45.35		PF+	1	29.90	52.40
	PF+	1	19.80	49.40		PF+	1	0.80	2.65
	PF+	1	28.05	50.65		PF+	1	0.05	1.60
	PF+	1	19.95	41.10		PF+	1	5.70	8.60
	PF+	1	0.75	0.35		PF+	1	1.70	1.70
	EXT (s) BL	7	95.28	117.81		EXT (ns) BL	9	56.20	79.45
			2.28	*5.27*				*2.02*	*4.01*
	EXT (s)	1	76.85	79.15		EXT (ns)	1	49.25	64.35
	EXT (s)	1	30.60	31.10		EXT (ns)	1	24.15	32.25
	EXT (s)	1	13.55	27.95		EXT (ns)	1	20.80	39.15
	EXT (s)	1	4.25	13.95		EXT (ns)	1	27.60	42.15
	EXT (s)	1	3.90	9.95		EXT (ns)	1	12.70	24.75
	EXT (ns) BL	12	86.99	97.48		EXT (s) BL	9	49.49	63.64
			4.43	*6.30*				*3.61*	*5.81*
	EXT (ns)	1	26.80	45.25		EXT (s)	1	45.40	58.15
	EXT (ns)	1	9.15	21.55		EXT (s)	1	21.05	28.10
	EXT (ns)	1	9.75	34.70		EXT (s)	1	9.55	20.45
	EXT (ns)	1	2.70	18.65		EXT (s)	1	7.65	26.50
	EXT (ns)	1	4.90	24.30		EXT (s)	1	3.35	7.70

APPENDIX 1

(Continued)

Low group					High group				
			Component					Component	
Pigeon	Condition	Sessions	VI	VI+S	Pigeon	Condition	Sessions	VI	VI+S
202	PF BL	36	71.74	57.15	220	PF BL	36	72.25	98.13
			6.66	*3.89*				*4.34*	*6.00*
	PF	1	49.50	41.90		PF	1	66.70	104.35
	PF	1	50.30	50.25		PF	1	54.15	99.30
	PF	1	44.10	39.55		PF	1	49.90	94.35
	PF	1	44.85	40.65		PF	1	55.30	88.70
	PF	1	44.95	35.85		PF	1	53.20	74.75
	PF+BL	9	59.38	64.38		PF+BL	8	76.81	86.31
			7.99	*6.10*				*6.29*	*6.97*
	PF+	1	34.50	47.60		PF+	1	80.75	99.90
	PF+	1	0.55	0.35		PF+	1	43.95	65.90
	PF+	1	33.75	42.50		PF+	1	28.45	49.80
	PF+	1	35.30	37.55		PF+	1	61.60	70.85
	PF+	1	21.20	28.40		PF+	1	39.15	58.10
	EXT (s) BL	6	67.40	54.81		EXT (s) BL	11	83.72	92.83
			3.07	*4.97*				*3.23*	*6.86*
	EXT (s)	1	53.60	52.85		EXT (s)	1	73.50	82.65
	EXT (s)	1	15.55	15.50		EXT (s)	1	30.45	33.85
	EXT (s)	1	12.20	10.35		EXT (s)	1	11.20	13.00
	EXT (s)	1	4.70	7.15		EXT (s)	1	12.45	17.05
	EXT (s)	1	4.50	3.20		EXT (s)	1	13.25	23.75
	EXT (ns) BL	6	61.14	56.41		EXT (ns) BL	11	77.00	102.13
			4.43	*3.13*				*3.71*	*3.92*
	EXT (ns)	1	19.35	13.55		EXT (ns)	1	79.30	91.25
	EXT (ns)	1	12.25	12.10		EXT (ns)	1	25.80	31.50
	EXT (ns)	1	9.80	18.60		EXT (ns)	1	28.25	31.10
	EXT (ns)	1	25.35	32.05		EXT (ns)	1	33.90	41.05
	EXT (ns)	1	3.10	4.85		EXT (ns)	1	8.25	13.00
217	PF BL	31	64.24	60.13	223	PF BL	30	88.73	83.75
			3.64	*3.20*				*4.70*	*3.64*
	PF	1	57.60	51.40		PF	1	84.80	93.80
	PF	1	48.60	54.60		PF	1	96.65	89.40
	PF	1	42.35	58.10		PF	1	87.50	77.05
	PF	1	35.60	38.70		PF	1	83.25	88.45
	PF	1	36.95	42.10		PF	1	87.60	88.50
	PF+BL	12	63.06	54.18		PF+BL	18	102.27	93.02
			4.47	*2.79*				*10.37*	*8.33*
	PF+	1	41.90	45.40		PF+	1	99.25	94.45
	PF+	1	0.00	0.00		PF+	1	23.30	22.85
	PF+	1	40.15	47.15		PF+	1	90.75	98.15
	PF+	1	18.45	21.70		PF+	1	63.35	59.90
	PF+	1	0.00	0.00		PF+	1	104.20	94.80
	EXT (s) BL	8	58.38	59.13		EXT (ns) BL	20	121.23	67.95
			2.39	*2.93*				*5.49*	*4.79*
	EXT (s)	1	67.65	61.85		EXT (ns)	1	114.35	80.20
	EXT (s)	1	24.35	30.05		EXT (ns)	1	59.00	43.40
	EXT (s)	1	17.40	18.45		EXT (ns)	1	37.85	28.50
	EXT (s)	1	22.00	33.60		EXT (ns)	1	3.25	13.45
	EXT (s)	1	24.00	30.95		EXT (ns)	1	1.30	4.20
	EXT (ns) BL	12	63.58	61.37		EXT (s) BL	8	132.02	80.48
			1.07	*4.80*				*8.25*	*4.34*
	EXT (ns)	1	46.15	40.90		EXT (s)	1	13.95	18.30
	EXT (ns)	1	28.20	23.15		EXT (s)	1	130.75	86.75
	EXT (ns)	1	22.05	17.85		EXT (s)	1	20.70	17.80
	EXT (ns)	1	40.50	29		EXT (s)	1	15.40	7.55
	EXT (ns)	1	14.10	9.15		EXT (s)	1	38.75	35.35

APPENDIX 2

Mean responses per min from successive baselines (BL) and individual sessions of disruption in the High and Low components. Conditions are presented in the order they occurred with the number of sessions per condition. Disrupters included presession feeding (PF), extinction with stimuli [EXT(s)], and extinction with no stimuli [EXT(ns)] for individual pigeons. Response-rate standard deviations are presented in italics.

			Component					Component	
Pigeon	Condition	Sessions	High	Low	Pigeon	Condition	Sessions	High	Low
39	PF BL	20	59.30	83.62	97	PF BL	32	71.02	72.84
			2.65	*2.65*				*3.35*	*2.67*
	PF	1	56.40	75.20		PF	1	4.50	11.60
	PF	1	14.70	16.25		PF	1	30.05	49.80
	PF	1	7.65	7.05		PF	1	38.15	56.70
	PF	1	8.90	7.75		PF	1	20.90	36.35
	PF	1	33.80	54.95		PF	1	45.10	69.40
	EXT (s) BL	6	68.22	92.09		EXT (ns) BL	7	85.70	75.28
			2.83	*4.02*				*4.00*	*2.99*
	EXT (s)	1	62.15	87.15		EXT (ns)	1	69.35	61.75
	EXT (s)	1	49.10	78.5		EXT (ns)	1	53.10	54.40
	EXT (s)	1	17.90	31.65		EXT (ns)	1	20.00	23.65
	EXT (s)	1	19.65	33.00		EXT (ns)	1	23.85	19.85
	EXT (s)	1	17.45	27.45		EXT (ns)	1	14.70	14.45
	EXT (ns) BL	8	57.74	92.30		EXT (s) BL	6	71.05	70.57
			5.97	*7.44*				*2.55*	*2.27*
	EXT (ns)	1	40.65	65.50		EXT (s)	1	27.85	29.90
	EXT (ns)	1	24.20	44.90		EXT (s)	1	27.50	34.10
	EXT (ns)	1	13.45	21.55		EXT (s)	1	21.75	27.65
	EXT (ns)	1	9.35	21.80		EXT (s)	1	22.20	30.80
	EXT (ns)	1	7.95	16.40		EXT (s)	1	16.10	18.80
202	EXT (s) BL	41	67.18	56.87	217	EXT (ns) BL	20	51.71	69.46
			1.01	*1.84*				*1.27*	*2.79*
	EXT (s)	1	17.10	16.30		EXT (ns)	1	42.75	65.10
	EXT (s)	1	62.55	56.30		EXT (ns)	1	43.40	53.70
	EXT (s)	1	41.60	43.60		EXT (ns)	1	37.30	57.50
	EXT (s)	1	43.85	48.40		EXT (ns)	1	14.40	20.70
	EXT (s)	1	6.05	9.75		EXT (ns)	1	8.65	10.70
	EXT (ns) BL	10	58.98	59.68		EXT (s) BL	10	46.94	58.14
			7.37	*6.53*				*4.53*	*3.72*
	EXT (ns)	1	38.15	43.20		EXT (s)	1	27.75	39.10
	EXT (ns)	1	14.15	21.45		EXT (s)	1	35.80	43.45
	EXT (ns)	1	6.70	5.70		EXT (s)	1	19.10	26.45
	EXT (ns)	1	8.00	6.55		EXT (s)	1	32.90	42.65
	EXT (ns)	1	16.35	22.50		EXT (s)	1	18.50	27.40
	PF BL	6	60.82	64.03		PF BL	14	37.63	59.68
			4.28	*2.28*				*1.10*	*3.38*
	PF	1	53.05	49.65		PF	1	34.20	46.25
	PF	1	1.75	4.70		PF	1	29.80	39.40
	PF	1	2.55	3.60		PF	1	17.10	20.80
	PF	1	54.35	46.85		PF	1	18.50	21.20
	PF	1	50.25	37.80		PF	1	8.80	12.25