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Conditioned Reinforcement by Stimuli Correlated and Uncorrelated with a Schedule of Food Reinforcement

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Conditioned Reinforcement by Stimuli Correlated and Uncorrelated with a Schedule of Food Reinforcement

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ABSTRACT

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Lillian Skiba-Thayer

A conditioned reinforcer derives its function from a relation to an established reinforcer. Respondent views suggest that a stimulus acquires reinforcing properties because it is positively correlated with an established reinforcer. Alternatively, the information hypothesis suggests that a stimulus acquires reinforcing properties because it reduces uncertainty about the likelihood of an established reinforcer. Observing response procedures have been used to evaluate the function of stimuli positively correlated (S+), negatively correlated (S-), and uncorrelated (S1, S2) with established reinforcers such as food (with animals) or money (with humans). Verbal instructions have been shown to alter the extent to which correlated and uncorrelated stimuli reinforce responding in human subjects (Perone & Kaminski, 1992). The present experiment assessed the reinforcing function of these stimuli with subjects not susceptible to instructional control – pigeons. The pigeons earned food reinforcers by pecking a key on a compound schedule: A variable-interval 60-s schedule of food reinforcement alternated irregularly with extinction. On each side of the food key was an observing key. Observing pecks produced, intermittently, brief displays of the stimulus correlated or uncorrelated with the ongoing component of the food schedule. The reinforcing function of the correlated and uncorrelated stimuli was assessed by manipulating the consequences of responding on the two observing keys across three comparisons: (a) S+ and S- *vs.* S1 and S2, (b) S+ *vs.* S1, and (c) S- *vs.* S2. Consistent with respondent accounts of conditioned reinforcement, S+ functioned as a conditioned reinforcer in that is maintained responding, and S-, S1, and S2 did not.

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Conditioned Reinforcement by Stimuli Correlated and Uncorrelated with a Schedule of Food Reinforcement

Human behavior is reinforced not only by biologically relevant stimuli such as food, water, and sex but also by stimuli that derive their reinforcing function from a history of learning such as grades, social status, and money. The latter have been said to be a necessary bridge between the methods and concepts of the basic animal laboratory and the world of human affairs (Dinsmoor, 1983; Honig, 1969).

A conditioned reinforcer is defined as a stimulus whose reinforcing function derives from a relation to an established reinforcer. Research has been concerned with the nature of this relation. The common view (Fantino, 1977; Kimble, 1961; Mackintosh, 1974) is that the relation is respondent: An otherwise neutral stimulus comes to function as a reinforcer because it is positively correlated with an established reinforcer. An alternative view focuses on the informative properties of a conditioned reinforcer (Berlyne, 1957; Hendry, 1969): An otherwise neutral stimulus comes to function as a reinforcer because it reduces uncertainty about the occurrence of an established reinforcer.[1] These two views overlap in the predictions they make about the function of stimuli positively correlated with an established reinforcer but differ in predictions about the function of stimuli negatively correlated with an established reinforcer. Studies with human participants have had conflicting findings on the relation required for conditioning to occur. The present study addressed these conflicting findings by eliminating variables that may have confounded the results of studies conducted with human participants.

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[1] A third view that has been gaining momentum is that these stimuli do not acquire reinforcing properties at all, but rather guide behavior toward reinforcing events (Bolles, 1975; Staddon, 1983; see Shahan, 2010, 2013 for reviews). The present research was designed to address predictions in the respondent realm.

Respondent Conditioning

The earliest views of conditioned reinforcement identified respondent conditioning as the relevant process. In a typical respondent conditioning procedure, a neutral stimulus, for example a tone, precedes the delivery of an unconditioned stimulus (US), for example food. After repeated tone-US presentations, the tone elicits the response that is elicited by the US, for example salivation. The tone is then said to function as a conditioned stimulus (CS). Anrep (1920) conducted an early demonstration of this process with two dogs in a salivary conditioning study. A tone (CS) was occasionally presented for 5 s and followed by the delivery of meat powder (US). After repeated CS-US presentations, the dogs began to salivate (conditioned response [CR]) when the tone was presented. Schneiderman et al. (1962) conducted a respondent conditioning procedure with rabbits in an eyeblink conditioning study. The CS was a tone, and the US was a puff of air delivered to the cornea that elicited an eyeblink response. After repeated CS-US presentations, the tone elicited the eyeblink response. Respondent conditioning has been demonstrated with a number of different CSs, USs, and CRs (see Mackintosh, 1974 for review). Hull (1943) suggested that a CS may acquire reinforcing properties as well as eliciting properties. He proposed that if the US will maintain responding when presented as a consequence of responding, then the CS will also maintain responding.

An early illustration of the necessary and sufficient conditions for establishing a conditioned reinforcer comes from a study by Egger and Miller (1962). Rats were trained to press levers on a fixed-ratio 1 (FR 1) schedule of food delivery, in which each response produced food. The ratio was gradually increased until responding was maintained on an FR 4 schedule. The lever was then removed from the chamber for conditioning sessions. The rats were divided into two groups: the *redundant* group and the *informative* group. In both groups, food was delivered at variable time periods that averaged 56 s. In the redundant group, a flashing light and a tone preceded food deliveries.[2] The flashing light was presented 2 s before the food delivery, and the tone was presented 1.5 s before the food delivery. Both stimuli were reliable predictors of food, but the tone was redundant to the flashing light. The procedure was similar for rats in the informative group with one exception. In addition to the light-tone-food sequence described above, every 30 s on average, the flashing light was presented alone for 2 s so that the light was not a reliable predictor of food. The tone alone was informative because it was the only stimulus that reliably preceded the delivery of food.

The functions of the flashing light and tone were then examined in two test sessions in which the lever was reinserted into the chamber. A single test session was conducted for each stimulus. Lever pressing was reinforced on an FR 3 schedule of food delivery until 30 pellets were delivered. After the delivery of 30 pellets, an extinction (EXT) period began in which lever pressing had no programmed consequences for 10 minutes. Following the EXT period, lever pressing produced the stimulus being tested according to an FR 3 schedule. The sequence described above was replicated for the second test session, except that the other stimulus was produced following the EXT period.

The effectiveness of each stimulus as a conditioned reinforcer was measured by the number of responses the stimulus supported in the test condition. The results were analyzed between groups. The flashing light functioned as a more effective conditioned reinforcer when it was a reliable predictor of food (redundant group) than when it was not a reliable predictor of food (informative group). The tone functioned as a more effective conditioned reinforcer when it was the only reliable predictor of food (informative group) than when it was redundant to the

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[2] The order in which the stimuli were presented was counterbalanced across rats. One order is described here for ease of explanation.

flashing light (redundant group). These findings shed light on the necessary and sufficient conditions for establishing a conditioned reinforcer. In addition to repeated CS-US presentations, the CS must be positively correlated with food and non-redundant. When a stimulus was occasionally presented alone, rendering the stimulus uncorrelated with food, it did not acquire reinforcing properties. When a stimulus was redundant to a second reliable predictor of food, the redundant stimulus did not acquire reinforcing properties.

Fantino (1977) developed an account of conditioned reinforcement that is consistent with respondent accounts but is expressed in terms of the temporal relations between a stimulus onset and an established reinforcer. His “delay reduction hypothesis” states that the strength of a stimulus as a conditioned reinforcer is a function of the reduction in time to an established reinforcer signaled by the onset of that stimulus: A stimulus whose onset signals a reduction in the delay to an established reinforcer will function as a conditioned reinforcer. A stimulus that signals no change in the delay to reinforcement will function as neutral, and a stimulus that signals an increase in the delay to reinforcement will function as a conditioned punisher. The delay reduction hypothesis can also be conceptualized in terms of the rate or probability of reinforcement in the presence of a stimulus. A stimulus that signals an increase in the rate or probability of reinforcement will function as a conditioned reinforcer. A stimulus that signals a decrease in the rate or probability of reinforcement will function as a conditioned punisher. A stimulus that signals no change in the rate or probability of reinforcement will function as neutral.

The results of two experiments conducted by Dinsmoor and his colleagues are consistent with the delay reduction hypothesis. Dinsmoor, Brown, and Lawrence (1972) trained pigeons on a compound schedule of food reinforcement in which two component schedules alternated at irregular intervals. In one component, pecks on a key were reinforced with food on a variable-interval (VI) schedule. Pecks produced food at variable intervals averaging 45 s or 120 s, depending on the pigeon. In the other component, pecks were never reinforced: the schedule was EXT. In the initial phase of the experiment, colors served as discriminative stimuli correlated with VI and EXT components. The key was lit green when the VI component was in effect and red when EXT was in effect. Green was designated “S+” because it was positively correlated with food and red as “S-” because it was negatively correlated with food. Responding was maintained in the VI component but not in the EXT component. In the subsequent conditions, the key colors were withheld. The key was lit white in both components unless the pigeon pecked a second key. This key, the observing key, produced 30-s presentations of the discriminative stimulus correlated with the ongoing schedule on the food key. Observing pecks produced the stimuli on a VI 30-s schedule. If the component changed during a stimulus presentation, the stimulus changed accordingly for the remaining portion of the presentation. Next, observing pecks produced S+ when the VI component was in effect but had no programmed consequences when EXT was in effect. If the component changed from VI to EXT during the stimulus presentation, the rest of the presentation was terminated and the food key was relit white. In the final condition, observing pecks produced S- when EXT was in effect but had no programmed consequence when the VI component was in effect; S- was terminated if the component changed during the 30-s presentation.

The irregular component durations in conjunction with the intermittent observing schedule prevented the absence of a consequence of observing coming to function as a discriminative stimulus in its own right. When the pigeon pecked the key that occasionally produced S+ and did not get a stimulus, this did not serve as a discriminative stimulus for EXT because, in fact, almost every time the pigeon pecked the observing key no stimulus was presented.

Figure 1 shows the observing response rates obtained by Dinsmoor et al. (1972). When observing could produce both S+ and S- (black bars) or S+ alone (green bars), responding was maintained. When observing could produce S- alone, responding extinguished.

Because S+ maintained responding on the observing key when it was the sole consequence, S+ clearly functioned as a conditioned reinforcer. By comparison, S- did not function as a conditioned reinforcer as it did not maintain responding when it was the sole consequence. Comparison of the black and green bars in Figure 1 suggests that S- may have functioned as a conditioned punisher. When observing pecks produced S- as well as S+, rates were lower for four of the five pigeons than when S+ was available alone. It is possible that S- suppressed observing response rates.

Mulvaney, Dinsmoor, Jwaideh, and Hughes (1974) further investigated the function of S-. As in the previous experiment, a VI schedule of food reinforcement alternated irregularly with EXT on the center key. The key was lit green (S+) when the VI component was in effect, and red (S-) when EXT was in effect. In the subsequent conditions, there were two observing keys rather than just one. The left and right keys served as the observing keys, and pecks on each could produce stimuli according to independent VI 30-s schedules. The stimulus presentations lasted 30 s. In the absence of the stimulus presentations, the three keys were lit yellow. In the first condition, both S+ and S- were available on each observing key. In the other condition, S+ and S- continued to be available on one key, while only S+ was available on the other key. Observing response rates were lower on the key that produced S- as well as S+ than on the key that produced only S+. This result provides conclusive evidence that S- suppressed responding. If S-functioned as a conditioned reinforcer, the key that produced both S+ and S- should have maintained higher rates of observing. If S- was a neutral stimulus, the key that produced both S+ and S- should have maintained the same rates of responding. These findings, in concert with those of Dinsmoor et al. (1972) support the delay reduction hypothesis prediction that S- will function as a conditioned punisher because it signals a period in which food is unavailable (i.e., a reduction in the rate of food reinforcement).

Human Observing

Perone and Baron (1980) replicated Mulvaney et al.'s (1974) concurrent observing response procedure with humans. The subjects were male industrial workers who were recruited through their labor unions. As in the previous studies with pigeons, the men were trained on a compound schedule with irregularly alternating VI and EXT components, each correlated with a color. Instead of food, the established reinforcer was money, and instead of a key peck, the response was pulling a plunger with 22 N of force. In subsequent conditions, the colors were absent unless the men pressed an observing key. Both observing keys were lit white and could produce the stimuli according to independent VI 30-s schedules. The stimulus presentations lasted 15 s. Perone and Baron compared the functions of S+ and S- in a more expansive set of comparisons than Mulvaney et al. (1974). They compared S+ and S- *vs.* S+ alone, S+ and S- *vs.* S- alone, and S+ alone *vs.* S- alone. Each observing comparison was in effect for 8 to 24 sessions with each session lasting 25 min, until observing was stable.

When observing could produce both S+ and S- or S+ alone, the men responded at a higher rate on the observing key that produced both S+ and S- than on the key that produced only S+. A similar result was obtained when observing could produce both S+ and S- or S- alone: Response rates were higher on the observing key that produced both S+ and S- than on the key that produced only S-. When observing could produce S+ or S-, two of the four men showed no consistent preference for either observing key. The other two men showed preferences, but for different stimuli: one man responded at a higher rate on the key that produced only S+ and the other man responded at a higher rate on the key that produced only S-.

In Mulvaney et al.'s (1974) experiment with pigeons, S- suppressed responding, but in Perone and Baron's (1980) experiment with humans, S- reinforced responding. According to the delay reduction hypothesis, S- should have functioned as a conditioned punisher because its onset signaled a decrease in the rate of monetary reinforcement. Perone and Baron's results aligned with the information theory (Berlyne, 1957), which holds that stimuli acquire reinforcing properties if they reduce uncertainty about the occurrence of an established reinforcer. Whereas information and respondent accounts agree that a stimulus positively correlated with an established reinforcer should function as a conditioned reinforcer, they part ways on the function of a stimulus negatively correlated with an established reinforcer. According to respondent accounts, S- should function as a conditioned punisher. According to the information account, S- should function as a conditioned reinforcer because it reduces uncertainty about the likelihood of an established reinforcer. Put simply, the S- may be "bad news" but it is still news. Perone and Baron's results are consistent with the information theory because both S+ and S- functioned as conditioned reinforcers.

Fantino and Case (1983, Experiments 1 and 2) attempted to reconcile Perone and Baron's (1980) findings regarding S- with the delay reduction hypothesis. To do so, they needed to explain how S- could function as a reinforcer despite its negative correlation with monetary reinforcement. They argued that S- may have functioned as a conditioned reinforcer in Perone and Baron's experiment because of the 22-N effort involved in the plunger response required to obtain monetary reinforcers. The EXT component represented a break from this relatively effortful response and, because of this, it is possible that the S- correlated with this break came to function as a reinforcer. To address this issue, Fantino and Case conducted an experiment in which points exchangeable for money were delivered to college students on a compound schedule. In one component, the money was delivered independently of responding at variable times averaging 60 s (a variable time [VT] schedule). In the other component, money was never delivered (EXT). Sessions consisted of 30 component presentations, 15 of each type, each lasting 1 min. The components alternated in a random order. Two levers were available for observing responses. Pressing the levers produced colors. In some cases, the colors were correlated with the ongoing component, thus serving as S+ and S-. In other cases, the colors were uncorrelated with the ongoing component. These colors were termed “S1” and “S2”. Pressing the observing levers produced the stimuli according to independent VI 60-s schedules. When a stimulus was produced, it remained on for 30 s, or until the end of the component, whichever came first. Three comparisons between the stimuli were made: S+ *vs.* S-, S1 *vs.* S2, and S- *vs.* S1. Each comparison was in effect for one 30-min session.

Before each session, the students were given instructions about the stimulus-reinforcer relations. The instructions described S+ and S- this way:

> In front of you are two levers and some lights. The white light will normally be on. You can occasionally cause the blue or red lights to turn on by pressing the levers. When the blue light is on, points are twice as likely as normal. In contrast, no points will be earned when the red light is on. (p. 196)

An uncorrelated stimulus was described by replacing the second sentence of these instructions with the following:

> When the blue light is on, some of the time points are twice as likely as normal. However, at other times when the blue light is on, no points will be earned. (p. 196)

Figure 2 summarizes the results of Fantino and Case's (1983) experiments. Observing response rates were obtained by combining the data from every student across the three conditions in their Experiments 1 and 2. Observing was maintained throughout the experiment. Rates were highest when the consequence was S+, intermediate when the consequence was S1 or S2, and lowest when the consequence was S-.

Fantino and Case (1983) interpreted their results as consistent with the delay reduction hypothesis. Their interpretation was based on S+ maintaining the highest rate of responding compared to S1, S2, and S-. However, in opposition to the hypothesis, observing was maintained by stimuli uncorrelated with monetary reinforcement as well as the stimulus negatively correlated with monetary reinforcement. According to Fantino's own hypothesis, stimuli uncorrelated with monetary reinforcement and stimuli negatively correlated with monetary reinforcement should not acquire reinforcing properties because their onset does not signal an increase in the rate or probability of monetary reinforcement.

The results of Perone and Baron (1980) and Fantino and Case (1983) are inconsistent with respondent accounts of conditioned reinforcement. The maintenance of responding by S- in Perone and Baron aligns with the information account. The maintenance of responding by S1, S2, and S- in Fantino and Case contradicts both respondent and information accounts.

Perone and Kaminski (1992) suggested that the results of Fantino and Case's experiment should be understood not as an outcome of conditioning but rather as a form of instructional control. They argued that the instructions regarding the stimuli had certain implications and the students seemed to be acting on those implications. The instructions for the uncorrelated stimuli stated that in the presence of such stimuli points are sometimes twice as likely. The students may have interpreted this message to imply that responding to produce the uncorrelated stimuli will sometimes result in additional points. Furthermore, students had only 30 min of exposure to the stimulus-reinforcer contingencies. It is unlikely that this amount of exposure was sufficient for conditioning to occur. Fantino and Case's brief exposure stands in marked contrast with experiments with pigeons (Dinsmoor et al., 1972; Mulvaney et al., 1974) and Perone and Baron's (1980) experiment with humans, all of which gave subjects hours of exposure to the stimulus-reinforcer relations.

Perone and Kaminski (1992) conducted a series of experiments with college students that provided support for their interpretation. The students were trained on a compound schedule with irregularly alternating components. In one component, monetary reinforcement occurred on a VI 27-s schedule. In the other component, monetary reinforcement was unavailable (EXT). Extensive discrimination training prior to the observing response procedure exposed the students directly to the stimulus-reinforcer relations. In one experiment, their discriminative stimuli consisted of the same descriptive messages regarding the stimulus-reinforcer relations as in Fantino and Case's (1983) experiment. In another experiment, the messages were arbitrary. Table 1 lists the verbal stimuli that were displayed in boxes on a computer screen in both experiments (from Perone and Kaminski, 1992, p. 561).

Discrimination training consisted of three conditions. In the first condition, S+ was presented during the VI component and S- during EXT. In the second condition, S1 and S2 presentations alternated independently of the VI and EXT components. In the final condition, the correlated and uncorrelated stimuli were presented at the same time on the upper and lower portions of the screen, respectively. In the observing conditions, the components of the compound schedule alternated in the absence of the discriminative stimuli. Presses on the two observing keys occasionally produced stimulus presentations. When the messages were descriptive, the uncorrelated stimuli maintained a higher rate of responding than S-. This finding replicated the results of Fantino and Case (1983). When the messages were arbitrary, S- maintained a higher rate of responding than the uncorrelated stimuli. By reducing the influence of the students' verbal history, the arbitrary messages may have allowed the direct exposure to the stimulus-reinforcer contingencies to control observing behavior.

Eliminating the Role of Instructional Control

An unpublished experiment in our lab compared the functions of stimuli correlated and uncorrelated with food reinforcement using subjects that are not susceptible to instructional control – pigeons. A VI schedule of food reinforcement alternated irregularly with EXT on the food key. To give the pigeons extended exposure to the correlated and uncorrelated stimuli, discrimination-training sessions were divided into *correlated* and *uncorrelated* blocks that alternated in an ABAB fashion. In correlated blocks, the colors on the food key were correlated with the schedule components, thus serving as S+ and S-. In uncorrelated blocks, the colors alternated with the same kind of irregular intervals as the components but were uncorrelated with the components, thus serving as S1 and S2. Because of equipment limitations, S+ and S1 were the same key color and S- and S2 were the same key color. What distinguished the correlated and uncorrelated stimuli was the status of the houselight. For one pigeon, the houselight flashed during the correlated blocks and was continuously lit during the uncorrelated blocks. The reverse was true for the other pigeon. Discrimination training was conducted until responding was highly differentiated across S+ and S- (higher in S+) and undifferentiated across S1 and S2 (about equal in the two stimuli).

Two side keys were introduced as observing keys. The food and observing keys were lit white and the houselight was turned off unless the pigeon pecked one of the observing keys. Pecks on each could produce 30-s presentations of stimuli according to independent VI 30-s schedules. In addition to changing the key colors, observing pecks changed the state of the houselight to either flashing or constantly lit, depending on whether the stimulus produced was correlated or uncorrelated with the components. Three comparisons were conducted: S+ and S- *vs.* S1 and S2, S+ *vs.* S1, and S- *vs.* S2.

Figure 3 shows observing response rates in the last 5 sessions of every condition. When observing could produce S+ and S- or S1 and S2, the pigeons responded at a higher rate on the key that produced S+ and S-. When observing could produce S+ or S1, the pigeons responded at a higher rate on the key that produced S+. When observing could produce S- or S2, responding extinguished.

S+ functioned as a conditioned reinforcer and S- did not. Both S1 and S2 were uncorrelated with food reinforcement but S1 functioned as a conditioned reinforcer and S2 did not. These results are inconsistent with both respondent and information accounts of conditioned reinforcement. According to both accounts, S1 and S2 should have functioned as neutral. The physical similarity between S+ and S1, and between S- and S2, likely resulted in stimulus generalization. S1 may have maintained responding because of its physical similarity to S+ and S2 may have suppressed responding because of its physical similarity to S-. Only the state of the houselight differentiated an uncorrelated blue key, for example, from a correlated blue key. The state of the houselight was likely not sufficient to prevent generalization across the correlated and uncorrelated stimuli.

To address this issue, the present experiment replicated the previously described experiment, but with stimuli that are physically distinct. For two pigeons, S+ and S- were different colors and S1 and S2 were different shapes. The stimuli were reversed for the other pigeon so that S+ and S- were shapes and S1 and S2 were colors.

Method

Subjects

Results are reported from three male White Carneau pigeons. They were maintained at 80% (± 2%) of their free-feeding body weight by food reinforcers obtained during experimental sessions and supplemental feedings, if necessary, provided at least 30 min after sessions. Water was freely available in the home cage, which was in a temperature- and humidity-controlled room with a 12:12 hr light/dark cycle. A fourth pigeon was excluded from the study because of low observing-key response rates. The treatment of the pigeons, in and out of experimental sessions, complied with a protocol approved by West Virginia University’s Institutional Animal Care and Use Committee.

Apparatus

Sessions were conducted in three sound-attenuating chambers. During sessions, extraneous sounds were masked by a ventilation fan and white noise (80 dB) played through an 8-ohm speaker. The pigeon’s space within the chamber measured 34.3 cm long, 30 cm wide, and 37 cm high. General illumination was provided by a 28-v houselight (No.1820) located on the bottom left corner of the front panel. A 7-in ELO AccuTouch® five-wire resistive single-touch touchscreen monitor (Model No. 0700L; 800 pixels wide and 480 pixels high; 15.4 cm wide and

8.7 cm tall) was held to the panel by a metal faceplate. A photograph of the touchscreen and faceplate is shown in Figure 4. The faceplate had six circular openings (2.8 cm in diameter) to allow access to specific areas of the touchscreen. These openings were arranged in two rows of three, spaced 4.2-cm apart from center to center. The centers of the bottom and top rows of keys were located 23 cm and 27 cm above the floor of the chamber, respectively. The openings were activated as response keys when a color or image was visible through the opening. Only the bottom row of keys was used in the experiment. To create key colors, the red, green, and blue pixels on the screen were mixed in specific proportions to mimic the colors produced by various wavelengths of light, as described by Toegel, Toegel, and Perone (2021). Food reinforcers consisting of 3- or 4-s access to pellets (Purina Mills Nutriblend Green) were delivered through an illuminated (No. 1820 bulb) 5-cm x 6-cm rectangular aperture located approximately 6.7 cm below the lower edge of the center key. Pecks were recorded and experimental events controlled by a computer program written in Visual Basic. Additional information about the touchscreen chambers has been reported by Toegel et al.

Procedure

Sessions were conducted seven days per week at approximately the same time each day. To minimize any effects of handling in the trip from the vivarium to the laboratory, each session began with a 5-min blackout period. After the blackout, the houselight and one or more response keys were turned on. The houselight and keys were turned off during food reinforcers. Except in preliminary training, the center key will be referred to as the *food key* and the side keys as *observing keys*.

Preliminary Training

To establish responding on all three keys, a schedule of food reinforcement was programmed on every key, one at a time, according to the steps provided in Table 2. All six steps were programmed in each session. At each step, only one key was lit and operative ("operative key" in the table). Each step lasted until seven reinforcers were delivered, for a total of 42 reinforcers per session. In the first two sessions, each key was lit white. In the subsequent sessions, the center key was lit (across steps) with the various colors and geometric shapes listed in Table 2. This exposed the pigeons to the stimuli to be used in the experimental conditions. When a side key was operative, it was always white. In the first session, an FR 1 schedule was arranged. Thereafter, a VI schedule was arranged, starting with VI 5-s, and raised across sessions to VI 10-s, VI 20-s, VI 30-s, VI 45-s, and finally VI 60-s.

Discrimination Training

Next, the pigeons were exposed to stimuli that were either correlated or uncorrelated with the VI 60-s and EXT components of a compound schedule on the food key (the side keys were not used). The components alternated at irregular intervals, with presentations lasting between 15 s and 225 s. Half of each session was spent in the VI component and half in EXT.

Four stimuli were used. Two, designated as S+ and S-, were correlated with the VI and EXT components, respectively. The other two stimuli, designated as S1 and S2, alternated at the same rate and with the same range of durations as the schedule components, but in a fashion that rendered them uncorrelated with the components. The specific stimuli used as S+, S-, S1, and S2 in discrimination training are shown in Figure 5. Because of an apparent color bias that was revealed during discrimination training, stimuli containing the color red were replaced by stimuli containing the color yellow for Pigeon 90.

Each 64-min session was divided into four blocks, each lasting 16 min. During the *correlated blocks*, S+ and S- alternated on the food key in concert with the VI and EXT components. During the *uncorrelated blocks*, S1 and S2 alternated independently of the VI and EXT components. The correlated and uncorrelated blocks strictly alternated. The first block of each session was randomly determined to be either correlated or uncorrelated. Therefore, in approximately half of the sessions, the odd-numbered blocks were correlated and the even-numbered blocks were uncorrelated; in the other sessions, the correlated and uncorrelated blocks were reversed.

Discrimination training continued until stimulus control was evident in the correlated blocks and absent in the uncorrelated blocks. To quantify stimulus control, two discrimination indices were calculated. The index for the correlated blocks was calculated by dividing each session’s response rate in S+ by the sum of rates in S+ and S-. The index of the uncorrelated blocks was calculated by dividing each session’s response rate in S1 by the sum of rates in S1 and S2. Discrimination training continued for a minimum of 20 sessions, and until there were 10 consecutive sessions with a correlated index between .90 and 1.00 (Pigeons 1108, 88, and 90) and, in most cases, an uncorrelated index between .40 and .60 (Pigeons 1108 and 88). Pigeon 90 consistently responded at a higher rate in the presence of S2 than in the presence of S1, which occasionally resulted in an uncorrelated index below .40 in the terminal 10 sessions of discrimination training.

Observing

The experimental conditions were designed to assess the potential reinforcing functions of the correlated and uncorrelated stimuli by providing these stimuli, in various combinations across conditions, as consequences of responding on the observing keys. At the start of the session, the three keys were white. On the food key, the VI 60-s and EXT components of the compound schedule continued to alternate irregularly. Each observing key was associated with an independent VI schedule. To facilitate the acquisition of observing, the initial VI schedule was VI 5-s. Thereafter, the schedule was raised to VI 15-s and finally to VI 30-s. Fulfilling the schedule requirement on one of the observing keys changed all three keys from white to a correlated or uncorrelated stimulus for a period of time, as described below.

The six experimental conditions were organized into pairs. Across all conditions, pecks on one observing key produced one or more correlated stimuli and pecks on the other observing key produced one or more uncorrelated stimuli. The first pair of conditions compared the functions of both correlated stimuli *vs.* both uncorrelated stimuli. The second pair compared the functions of S+ *vs.* S1, and the last pair compared the functions of S- *vs.* S2. The second condition of each pair was simply a reversal of the first condition. Reversals were conducted to verify that the stimuli programmed on the observing keys were responsible for any differential rates of responding across the two keys.

In the first pair of conditions, responses on one key produced S+ and S-, and responses on the other key produced S1 and S2. A peck that satisfied the schedule on one observing key produced S+ if the current component on the food key was VI and S- if the component was EXT. If the component changed during the 30-s stimulus presentation, the correlated stimulus changed accordingly. A peck that satisfied the schedule on the other observing key produced either S1 or S2, depending on the state of the system that determined the sequence of uncorrelated stimuli. If the state of this system changed during the 30-s stimulus presentation, the uncorrelated stimulus changed accordingly.

In the second pair of conditions, responses on one key produced S+ and responses on the other key produced S1. Observing responses on one key occasionally produced S+ only when the VI component was underway on the food key. If the component changed during the 30-s stimulus presentation, the remainder of the presentation was canceled. Observing responses on the other key occasionally produced S1 only when the uncorrelated stimulus system was in the S1 state. If the state changed to S2 during the 30-s stimulus presentation, the remainder of the presentation was canceled.

In the final pair of conditions, observing responses on one key produced S- and responses on the other key produced S2. Observing responses on one key produced S- only when the EXT component was underway on the food key. If the component changed during the 30-s stimulus presentation, the remainder of the presentation was canceled. Observing responses on the other produced S2 only when the uncorrelated stimulus system was in the S2 state. If the state changed to S1 during the stimulus presentation, the remainder of the presentation was cancelled. Pigeon 90 was excluded from these conditions because of decreased responding on both the food and observing keys.

In all observing conditions, a peck on the food key was not eligible for reinforcement within 2 s of an observing response. By preventing food from being delivered in temporal proximity to an observing response, this changeover delay reduced the chance that observing responses were adventitiously reinforced with food. The goal was to ensure that observing behavior was controlled solely by the production of the correlated and uncorrelated stimuli.

To increase the rate of responding on the observing response keys, the food reinforcer duration was increased from 3 s to 4 s. This change occurred in different conditions for the three pigeons.

The left half of Table 3 shows the observing conditions in order of presentation and the number of sessions in each condition. Replications of previous conditions that failed to maintain observing lasted at least 10 sessions. In most cases, observing conditions continued until there was no increasing or decreasing trend in the rate of responding on the left and right observing keys over five consecutive sessions. In replications of previous conditions, observing conditions were sometimes terminated prior to responding meeting the stability criterion. This occurred when the trend in the rate of responding on one observing key was in the opposite direction of the trend in the rate of responding predicted in the upcoming condition.

Remedial Training

Additional training for Pigeon 90 was required to establish observing. The strategy was to require the pigeon to produce a stimulus to activate the food key and obtain food reinforcement. At the start of the session, the food key was darkened and the left and right observing keys were white. Pecks on the observing keys produced stimuli on independent VI 10-s schedules. The VI and EXT components alternated on the food key as described above, but pecks on the food key had no effect. Pecks on the left observing key occasionally produced the stimulus correlated with the ongoing component, either S+ or S-, on the food key and both observing keys. Pecks on the right observing key occasionally produced either S1 or S2 on the food key and both observing keys. The stimuli were presented for 60 s, and alternated with the schedule components, or uncorrelated stimulus sequence, in the same manner as in the observing response procedure. In the presence of the stimuli, pecks on the food-key that fulfilled the schedule requirement during the VI component produced food.

Pigeon 90 responded almost exclusively on the right key, which produced the uncorrelated stimuli. Therefore, the training was not successful in exposing the pigeon to the stimuli available on both observing keys. Following a brief hiatus and re-exposure to discrimination training, the remedial training procedure was modified.

A forced-choice procedure was implemented to require Pigeon 90 to contact the stimuli available on both the left and right observing keys. At the start of the session only one observing key was active at a time. When an observing key was active, it was white, and pecks on the key could occasionally produce stimuli according to a VI 10-s schedule. The other observing key and the food key were dark and inactive. When the left key was active, pecks occasionally produced either S+ or S- depending on the ongoing schedule component on the food key, either VI or EXT. When the right key was active, pecks occasionally produced either S1 or S2. The stimuli were presented on the three keys for 60 s, and alternated with the schedule components, or uncorrelated stimulus sequence, in the same manner described above. In the presence of S+, S1, or S2, pecks on the food-key that fulfilled the schedule requirement during the VI component produced food. The sequence of alternation between the left and right observing keys was determined randomly. In this modification of remedial training, Pigeon 90 responded at higher rates on the key that produced S+ and S- than on the key that produced S1 and S2. This higher rate of responding was maintained when the stimuli available on the left and right observing keys were reversed. After the reversal, Pigeon 90 was again exposed to the observing response procedure.

Results

The results are based on the stable five sessions of discrimination training and each observing condition.

Discrimination Training

The left column of Figure 6 shows food key responses rates in the presence of each stimulus during discrimination training. All three pigeons responded at relatively high rates in the presence of S+ and relatively low rates in the presence of S-. Responding in S1 and S2 was high and undifferentiated for Pigeons 1108 and 88. Pigeon 90 responded reliably in the presence of S2 but rarely responded in the presence of S1, revealing a stimulus bias that persisted throughout the study.

The right column of Figure 6 converts these values into correlated and uncorrelated discrimination ratios. A discrimination ratio of 0.5 indicates equal rates of responding in the presence of the two stimuli. A discrimination ratio above 0.5 indicates higher rates of responding in the presence of S+ in the correlated discrimination ratio and S1 in the uncorrelated discrimination ratio. A discrimination ratio below 0.5 indicates higher rates of responding in the presence of S- in the correlated ratio and S2 in the uncorrelated ratio. The correlated discrimination ratios were at or near 1.0 for all three pigeons. The uncorrelated discrimination ratios approximated 0.5 for Pigeons 1108 and 88. Because Pigeon 90 responded at relatively low rates in the presence of S1, the uncorrelated discrimination ratio for this pigeon was close to 0.0.

Figure 7 shows the rate of reinforcement in the presence of each stimulus during discrimination training. The horizontal dashed lines show the programmed rates in S+ (1.0) and S1 and S2 (0.5). For Pigeons 1108 and 88, the obtained rates of reinforcement closely approximated the programmed rates. Obtained reinforcement rates were lower than the programmed rates across all of the stimuli for Pigeon 90, because this pigeon did not respond at a rate high enough to obtain all of the programmed reinforcers.

Observing

Figure 8 shows observing response rates in each observing condition, including the 3- and 4-s reinforcer magnitude manipulations. The conditions in the figure are presented in an order that focuses on each comparison when the stimuli available on the left and right observing keys were reversed (Table 3 lists the conditions in the order they were conducted). The first column shows the comparison between S+ and S- on one observing key and S1 and S2 on the other. Pigeon 1108 responded almost exclusively on the key that produced S+ and S-. This pattern of responding was evident both when S+ and S- were available on the left key and in the reversal when the stimuli were available on the right key. For Pigeon 88, when S+ and S- were available on the left key and S1 and S2 on the right key, the pigeon responded almost exclusively on the left key. In the reversal, Pigeon 88 almost never responded on either key. These findings reveal a side-key bias that continued across all conditions. Pigeon 88 almost never responded on the right key, regardless of the stimuli available on that key. A side-key bias was also apparent for Pigeon 90. When S+ and S- were available on the left key and S1 and S2 on the right key, Pigeon 90 responded at near-zero rates on both keys. However, when the stimuli available on the two keys were reversed, Pigeon 90 responded almost exclusively on the key that produced S+ and S-. In summary, the three pigeons responded almost exclusively on the key that produced S+ and S-.

The middle column of Figure 8 shows observing response rates when S+ was available on one observing key and S1 was available on the other. Because only one stimulus was produced on each observing key in this comparison, the function of S+ and S1 can be assessed independently. Pigeon 1108 responded on the key that produced S+ and almost never responded on the key that produced S1. Pigeon 88 responded on the left key when S+ was available on the left key and S1 was available on the right key. When S+ was available on the right key and S1 on the left, Pigeon 88 rarely responded on either key when the reinforcer duration was 3-s. When the reinforcer duration was increased to 4-s, Pigeon 88 responded at low rates on the key that produced S1 and almost never responded on the key that produced S+. However, response rates on the key that produced S1 trended downward. Unfortunately, because the 4-s reinforcer duration was a replication, the condition was terminated despite the downward trend. It is likely that response rates on this key would have decreased further with additional sessions in this condition. Pigeon 90 reached stability in only one condition in this comparison. In this condition, when S+ was available on the right key and S1 on the left, Pigeon 90 responded almost exclusively on the key that produced S+. In summary, S+ functioned as a conditioned reinforcer for all pigeons in this comparison.

The right column of Figure 8 shows observing response rates when S- was available on one key and S2 on the other. Pigeons 1108 and 88 responded at near-zero rates on both keys. This comparison was not conducted for Pigeon 90. Unfortunately, Pigeon 90’s rate of responding on the food key and both observing keys decreased to zero in a prior condition that did not reach stability. The pigeon’s responding did not recover and he was removed from the experiment. The results of this comparison reveal that responding on the key that produced S+ and S- in the first comparison was maintained by the production of S+.

The duration of food reinforcement was raised from 3- to 4-s to increase the rate of responding on the observing keys. In some cases, this did result in higher rates of observing on the key that produced S+. For Pigeon 1108, the effect of raising the food duration varied across conditions. Raising the food duration resulted in higher rates of observing when S+ and S- were available on the left key and S1 and S2 on the right key. However, there was no difference in the rate of responding across the two reinforcer durations when the side-key consequences were reversed. When S+ was available on the left key and S1 on the right key, raising the food duration resulted in a slight increase in the rate of responding on the left key. The effect of reinforcer duration cannot be assessed when S+ was available on the right key and S1 was available on the left key because the condition was not conducted with the 3-s food reinforcer duration. However, in the 4-s condition, observing response rates on the key that produced S+ were as high or higher than observing responses in all other conditions. The food duration had the most notable effect on Pigeon 88's observing. When S+ was produced on the left key (either alone or in combination with S-), raising the food duration increased the rate of observing on that key. The food duration had no effect on observing for Pigeon 90. The ability to analyze the effects of reinforcer duration on observing behavior is limited because this change was not implemented in each condition for all of the pigeons.

Figure 9 shows the time spent in each stimulus in each observing condition. Sessions with the 3- and 4-s food durations were aggregated in the calculation for each condition. The right half of Table 3 shows the results separately for each reinforcer duration. Sessions lasted for 64 mins, and all three pigeons spent the majority of each session in the mixed stimulus (shown in text in each panel). When S+ and S- were available on one key and S1 and S2 on the other (left column), the pigeons spent more time in S+ and S- than S1 and S2, in most cases. Because of the side key bias apparent with Pigeon 88, when S+ and S- were available on the right key and S1 and S2 on the left, the pigeon spent more time in S1 and S2, though each stimulus was only presented for less than one min. When S+ was available on one key and S1 on the other (center column), all three pigeons spent more time in S+ than in S1. When S- was available on one key and S2 on the other (right column), the pigeons spent very little time in either stimulus.

The left column of Figure 10 shows the response rates on the food key, collapsing across observing conditions. The right half of Table 4 shows the results separately for each observing condition. The patterns of responding in discrimination training were maintained in the observing conditions. All three pigeons responded at relatively high rates in the presence of S+ and low (Pigeons 1108 and 88) or zero (Pigeon 90) rates in S-. Pigeon 1108 responded at a higher rate in the presence of S1 compared to S2. Pigeon 88 responded at high and undifferentiated rates in the presence of S1 and S2. Pigeon 90 did not respond in the presence of S1 but reliably responded in the presence of S2. All three pigeons reliably responded on the food key in the presence of the mixed stimulus.

The right column of Figure 10 converts the food-key response rates into correlated and uncorrelated discrimination ratios. The ratios were similar to those obtained from discrimination training. The correlated discrimination ratio was at or near 1.0 for all three pigeons. The uncorrelated discrimination ratio was slightly above 0.5 for Pigeon 1108, approximately 0.5 for Pigeon 88, and 0.0 for Pigeon 90.

Figure 11 shows the rate of food reinforcement in the presence of each stimulus during the observing conditions, collapsing across the 3- and 4-s food reinforcer durations. The right half of Table 5 shows the results separately for each food reinforcer duration. The horizontal dashed lines show the programmed rate of reinforcement in the presence of S+ (1.0) and S1 and S2 (0.5). The figure excludes results for a stimulus if it was presented for less than 1.5 minutes per stable session. The rates of food reinforcement in the presence of each stimulus closely approximated the programmed rates in most cases. For Pigeon 90, the rate of food reinforcement in the presence of S+ was consistently lower than 1.0. For this pigeon, the rate of food reinforcement in the presence of the mixed stimulus was considerably lower than 0.5 when S+ was available on the right key and S1 was available on the left key.

Discussion

The present study was interested in the necessary relation between a stimulus and an established reinforcer for the stimulus to function as a conditioned reinforcer. The stimulus positively correlated with food reinforcement (S+) functioned as a conditioned reinforcer in that it maintained observing behavior. The stimulus negatively correlated with food (S-), and the stimuli uncorrelated with food (S1 and S2) did not function as conditioned reinforcers.

The study was a replication of an unpublished experiment conducted in our lab. In the prior study, S1 maintained observing and S2 did not. We hypothesized that the maintenance of responding by S1 occurred because of its physical similarity to S+. Due to equipment limitations, S+ and S1 were the same color and S- and S2 were the same color. The state of the houselight, either constant or flashing, was used to distinguish the correlated stimuli from the uncorrelated stimuli. S1 may have maintained responding because of its physical similarity to S+ and S2 may have suppressed responding because of its physical similarity to S-. To address this issue, the present study used four different stimuli for S+, S-, S1, and S2. For two pigeons, S+ and S- were different colors and S1 and S2 were different shapes. The stimuli were reversed for the other pigeon. Responding was not maintained by the production of S1 or S2. This indicates that the maintenance of responding by S1 in the prior study was because of its physical similarity to S+. Furthermore, the physical similarity between S- and S2 was not essential in the prior study for the failure of S2 to maintain responding.

The maintenance of observing by S+ aligns with Fantino's (1977) delay reduction hypothesis of conditioned reinforcement. The rate of food reinforcement in the presence of the mixed stimulus was 0.5 food reinforcers per minute. The rate of food reinforcement in the presence of S+ was 1.0. The onset of S+ signaled an increase in the rate of food reinforcement, and thus functioned as a conditioned reinforcer. The rate of food reinforcement in the presence of S1 and S2 was 0.5. The onset of S1 and S2 signaled no change in the rate of food reinforcement relative to the mixed stimulus, and thus functioned as neutral stimuli. The rate of food reinforcement in the presence of S- was zero. The onset of S- signaled a decrease in the rate of food reinforcement, and thus did not maintain responding. The present study did not arrange a condition to directly assess whether S- functioned as a conditioned punisher or a neutral stimulus. To assess the punishing function of S-, Mulvaney et al. (1974) arranged a condition in which S+ and S- were produced by observing on one key and S+ alone was produced by observing on a second key. Response rates were higher on the key that produced S+ alone, indicating that S- functioned as a conditioned punisher. In the present study, a direct assessment of the punishing function of S- was not arranged. Nonetheless, the results are consistent with the delay reduction hypothesis in that S- did not maintain observing.

Studies with human participants have had mixed results regarding the function of stimuli negatively correlated and uncorrelated with monetary reinforcers. In Perone and Baron's (1980) study, both S+ and S- maintained observing. As suggested by Fantino and Case (1983), S- likely maintained responding in Perone and Baron because it was correlated with a break from an effortful response. In Fantino and Case's study, S-, S1, and S2 maintained observing. The maintenance of observing by S-, S1, and S2 is inconsistent with both respondent and information accounts of conditioned reinforcement. Perone and Kaminski (1992) suggested that the instructions given to students in Fantino and Case's study influenced observing. By using pigeons as subjects, the present study allowed for an assessment of stimuli correlated and uncorrelated with reinforcement by eliminating the role of instructional control. The results provide support for Perone and Kaminski's suggestion that the maintenance of responding by S1 and S2 in Fantino and Case's study was not a result of conditioning, but rather a product of instructional control.

One curiosity of the present study was the overall low rates of observing compared to the prior study conducted in our lab. Observing response rates on the key that produced S+ and S- ranged from 0 to 12 responses per minute in the present study, and 5 to 35 responses per minute in the prior study. The difference in observing response rates between the two studies can be understood, at least in part, by differences in overall rates of responding. Food-key response rates in the presence of S+ ranged from 4 to 75 responses per minute in the present study, and 35 to 180 responses per minute in the prior study conducted in our lab. When observing response rates are considered relative to food-key response rates, the difference in observing response rates between the two studies was small.

The difference in food key response rates between the unpublished study in our lab and the present study is an interesting finding, given the procedural similarities between the two studies. With the exception of modifications to the physical properties of the stimuli used in the present experiment, the main difference between the two studies was the apparatus. The prior study in our lab used a standard operant chamber and the present study used a touchscreen chamber. In a standard operant chamber, the response keys are plastic discs connected to microswitches that register a response when the pigeon pecks with enough force to fully depress the key. The click of the microswitch produces auditory feedback and the movement of the key produces tactile feedback. In a touchscreen chamber, the “key” is a glass screen. When the pigeon pecks with enough force to register a response, a speaker in the chamber produces a feedback “click”. The ergonomics of the response devices are very different and that is reflected in the lower rates of responding.

One complication of the present study was the side-key biases apparent with Pigeons 88 and 90. An advantage of a two-key observing response procedure is the ability to compare two concurrently available alternatives. This procedure allows for an assessment of the relative rates of responding across the two observing keys to compare the function of the various stimuli both within and across conditions. For the two pigeons with side-key biases, the results must be interpreted across conditions. For example, Pigeon 88 responded almost exclusively on the left key. Therefore, the rate of responding on the left key was most effectively analyzed across conditions.

The logical next step in confirming the conclusions that have been drawn here is to replicate the experiment in a standard operant chamber to obtain higher response rates. As described above, low observing response rates in the present study complicated the analysis for two of the three pigeons. The technological limitations of the standard operant chamber that led us to use a touchscreen chamber could be addressed in the proposed study by using only four stimuli: the mixed stimulus, S+, S-, and S2. In the proposed study, a compound schedule of food reinforcement will be arranged. In one component, food will be delivered on a VI 60-s schedule. In the other component, food will never be delivered (EXT).

Discrimination training will be divided into correlated and uncorrelated blocks, as in the present study. In the correlated blocks, S+ will be presented during the VI component and S- during EXT. In the uncorrelated blocks, the mixed stimulus and S2 will alternate independently of the VI and EXT components. The use of the mixed stimulus during discrimination training will allow us to conduct the comparisons of interest in the observing conditions with only four stimuli, instead of five. In the observing conditions, the components of the compound schedule will alternate irregularly in the presence of the mixed stimulus. Two comparisons will be conducted: S+ *vs.* S2, and S- *vs.* S2. In the first comparison, we predict that S+ will maintain responding and S2 will not. In the second comparison, we predict that neither stimulus will maintain responding. The second comparison is critical because respondent accounts of conditioned reinforcement suggest that neither S- nor S2 should maintain observing. In the present experiment, this condition was only conducted with two pigeons and the reversal was only conducted with one pigeon.

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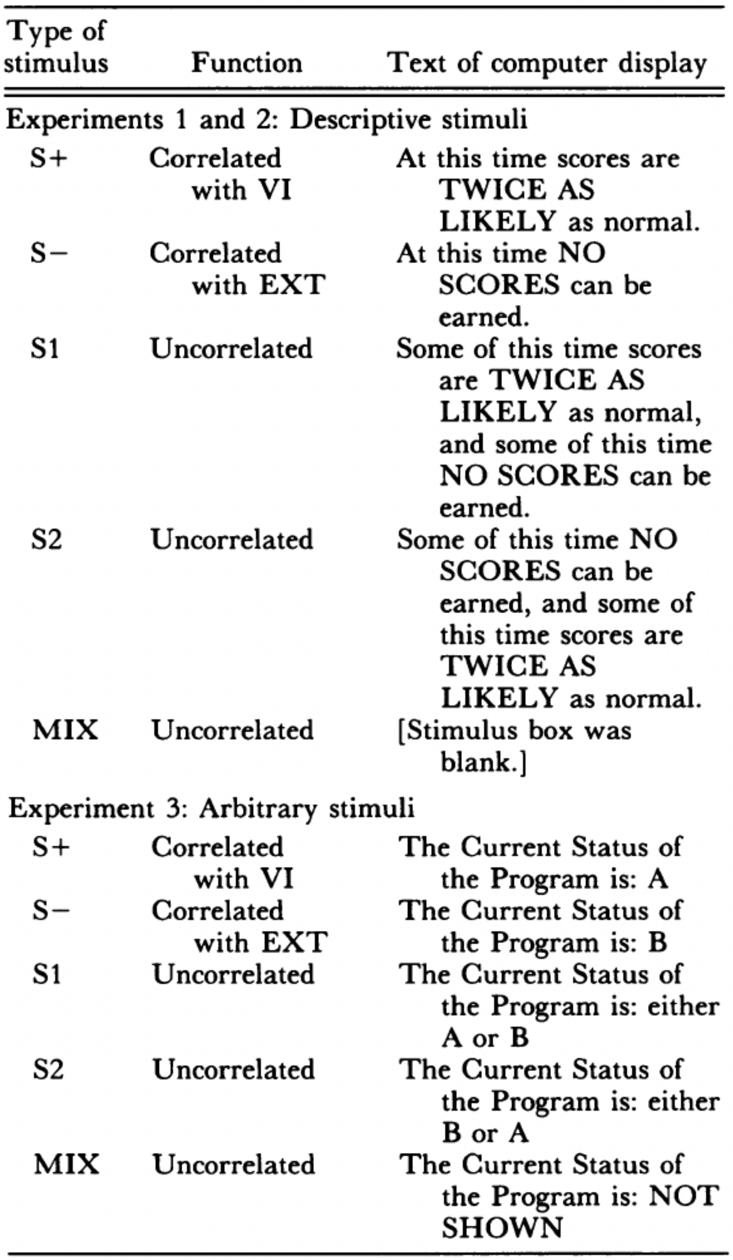
Table 1

Descriptive and Arbitrary Stimuli in Perone and Kaminski (1992)



Type of stimulus	Function	Text of computer display
Experiments 1 and 2: Descriptive stimuli		
S+	Correlated with VI	At this time scores are TWICE AS LIKELY as normal.
S−	Correlated with EXT	At this time NO SCORES can be earned.
S1	Uncorrelated	Some of this time scores are TWICE AS LIKELY as normal, and some of this time NO SCORES can be earned.
S2	Uncorrelated	Some of this time NO SCORES can be earned, and some of this time scores are TWICE AS LIKELY as normal.
MIX	Uncorrelated	[Stimulus box was blank.]
Experiment 3: Arbitrary stimuli		
S+	Correlated with VI	The Current Status of the Program is: A
S−	Correlated with EXT	The Current Status of the Program is: B
S1	Uncorrelated	The Current Status of the Program is: either A or B
S2	Uncorrelated	The Current Status of the Program is: either B or A
MIX	Uncorrelated	The Current Status of the Program is: NOT SHOWN

Note. Table 1 from Perone and Kaminski (1992, p. 561).

Table 2

Stimuli in Preliminary Training

		Session			
Step	Operative Key	1-2	3-4	5-6	7-*x*
1	Left	White	White	White	White
2	Center	White	Green	Red Square	Green
3	Center	White	Blue	Gray Square	Gray Square
4	Right	White	White	White	White
5	Center	White	Green	Red Square	Red Square
6	Center	White	Blue	Gray Square	Blue

Note. All six steps were programmed in each session of preliminary training. “Red Square” refers to a red square on a gray background. “Gray Square” refers to a gray square on a red background. In the rightmost column, $x = 36$ (Pigeons 1108 and 90) and 34 (Pigeon 88).

Table 3

Time Spent in Each Stimulus Across Reinforcer Durations in the Observing Conditions

	Stimuli Available		# of	Food	Stimulus				
					S+	S-	S1	S2	Mix
Pigeon	Left	Right	Sessions	Dur (s)	Minutes Spent in Stimulus				
1108	S+/S-	S1/S2	28	3	10.55 (1.70)	10.32 (1.07)	1.67 (0.93)	1.29 (0.58)	38.67 (3.74)
	S1/S2	S+/S-	21	3	7.90 (1.71)	8.79 (2.18)	1.42 (0.72)	0.53 (0.22)	44.11 (4.22)
	S+	S1	33	3	8.83 (0.85)	– –	1.91 (1.12)	– –	51.98 (1.64)
	S1	S+	20	4	13.81 (0.61)	– –	1.28 (0.77)	– –	46.96 (0.67)
	S+	S1	23	4	11.83 (0.52)	– –	1.28 (1.07)	– –	48.93 (1.46)
	S+/S-	S1/S2	18	4	11.11 (1.09)	13.84 (0.83)	1.61 (0.92)	1.32 (0.76)	34.12 (1.39)
	S-	S2	20	4	– –	3.39 (1.05)	– –	0.73 (0.65)	57.83 (1.60)
	S2	S-	21	4	– –	1.11 (0.75)	– –	1.47 (0.68)	59.52 (1.19)
	S1/S2	S+/S-	23	4	9.78 (1.25)	11.81 (0.94)	1.27 (0.70)	1.19 (0.68)	38.06 (1.15)
88	S+/S-	S1/S2	20	3	5.08 (1.14)	6.65 (0.65)	0.30 (0.24)	0.10 (0.20)	50.55 (1.29)
	S1/S2	S+/S-	20	3	0.10 (0.20)	0.10 (0.20)	0.82 (0.57)	1.43 (0.65)	60.05 (0.45)
	S1	S+	24	3	0.10 (0.20)	– –	0.90 (0.37)	– –	61.61 (0.59)
	S+	S1	31	3	3.62 (1.41)	– –	1.48 (0.71)	– –	57.49 (1.53)
	S+	S1	21	4	9.12 (1.31)	– –	0.34 (0.34)	– –	52.69 (1.36)
	S1	S+	13	4	0.18 (0.31)	– –	2.76 (1.14)	– –	59.24 (1.13)
	S+/S-	S1/S2	18	4	8.56 (0.98)	10.29 (1.37)	0.09 (0.17)	0.00 (0.00)	43.20 (2.23)
	S-	S2	20	4	– –	1.58 (1.31)	– –	0.09 (0.17)	60.28 (1.42)
90	S1/S2	S+/S-	26	3	5.78 (1.21)	7.58 (0.39)	0.79 (0.63)	0.81 (0.39)	47.63 (1.64)
	S+/S-	S1/S2	10	3	2.47 (0.76)	3.24 (1.97)	0.60 (0.37)	0.77 (0.44)	55.61 (2.69)
	S1/S2	S+/S-	22	4	7.01 (0.93)	8.79 (0.71)	0.05 (0.10)	0.05 (0.10)	46.57 (1.16)
	S+/S-	S1/S2	10	4	0.00 (0.00)	0.00 (0.00)	0.10 (0.20)	0.29 (0.38)	62.01 (0.43)
	S1	S+	29	4	12.87 (1.51)	– –	0.10 (0.20)	– –	50.06 (1.26)

Note. Stimulus times are shown as means with standard deviations in parentheses. The conditions are shown in order of exposure. The number (#) of sessions and food duration in seconds are shown for each condition.

Table 4

Food-Key Response Rates in the Presence of Each Stimulus Across Reinforcer Durations in the Observing Conditions

					Stimulus				
	Stimuli Available		# of	Food	S+	S-	S1	S2	Mix
Pigeon	Left	Right	Sessions	Dur (s)	Food-Key Responses Per Minute				
1108	S+/S-	S1/S2	28	3	70.89 (8.71)	1.60 (0.57)	46.15 (11.28)	30.55 (7.46)	54.98 (9.79)
	S1/S2	S+/S-	21	3	37.98 (6.17)	0.32 (0.20)	23.35 (9.67)	6.68 (5.32)	16.25 (7.18)
	S+	S1	33	3	35.43 (5.34)	– –	24.50 (3.57)	– –	12.71 (4.30)
	S1	S+	20	4	39.88 (9.63)	– –	20.82 (1.91)	– –	19.48 (4.97)
	S+	S1	23	4	38.21 (4.46)	– –	27.47 (6.32)	– –	21.19 (3.49)
	S+/S-	S1/S2	18	4	51.69 (6.41)	0.64 (0.15)	31.70 (3.90)	26.73 (5.12)	32.63 (8.47)
	S-	S2	20	4	– –	0.94 (0.74)	– –	9.30 (3.06)	50.47 (5.39)
	S2	S-	21	4	– –	1.84 (1.45)	– –	9.95 (9.31)	35.50 (13.20)
	S1/S2	S+/S-	23	4	28.04 (6.02)	0.34 (0.22)	29.75 (17.23)	17.17 (9.29)	21.67 (4.89)
88	S+/S-	S1/S2	20	3	13.18 (1.21)	0.29 (0.21)	7.50 (4.33)	12.00 (-)	10.71 (1.71)
	S1/S2	S+/S-	20	3	4.00 (-)	0.00 (-)	6.81 (3.86)	10.62 (2.39)	13.86 (1.17)
	S1	S+	24	3	20.00 (-)	– –	12.03 (4.08)	– –	9.58 (1.33)
	S+	S1	31	3	26.26 (4.43)	– –	12.33 (3.06)	– –	14.05 (3.22)
	S+	S1	21	4	23.36 (2.95)	– –	3.51 (1.70)	– –	10.67 (1.68)
	S1	S+	13	4	20.73 (0.52)	– –	10.94 (4.11)	– –	11.55 (1.62)
	S+/S-	S1/S2	18	4	28.13 (4.61)	0.43 (0.42)	16.15 (-)	– –	15.61 (1.17)
	S-	S2	20	4	– –	0.41 (0.50)	– –	6.92 (-)	19.94 (1.41)
90	S1/S2	S+/S-	26	3	15.02 (1.34)	0.03 (0.06)	0.00 (0.00)	10.19 (3.00)	10.15 (1.09)
	S+/S-	S1/S2	10	3	8.68 (4.13)	0.00 (0.00)	0.00 (0.00)	5.90 (1.18)	5.80 (1.44)
	S1/S2	S+/S-	22	4	4.38 (2.04)	0.00 (0.00)	0.00 (-)	0.00 (-)	3.92 (1.62)
	S+/S-	S1/S2	10	4	– –	– –	0.00 (-)	2.61 (0.61)	4.09 (2.44)
	S1	S+	29	4	1.28 (0.45)	– –	0.00 (-)	– –	0.65 (0.23)

Note. Food-key response rates are shown as means with standard deviations in parentheses. The conditions are shown in order of exposure. The number (#) of sessions and food duration in seconds are shown for each condition.

Table 5

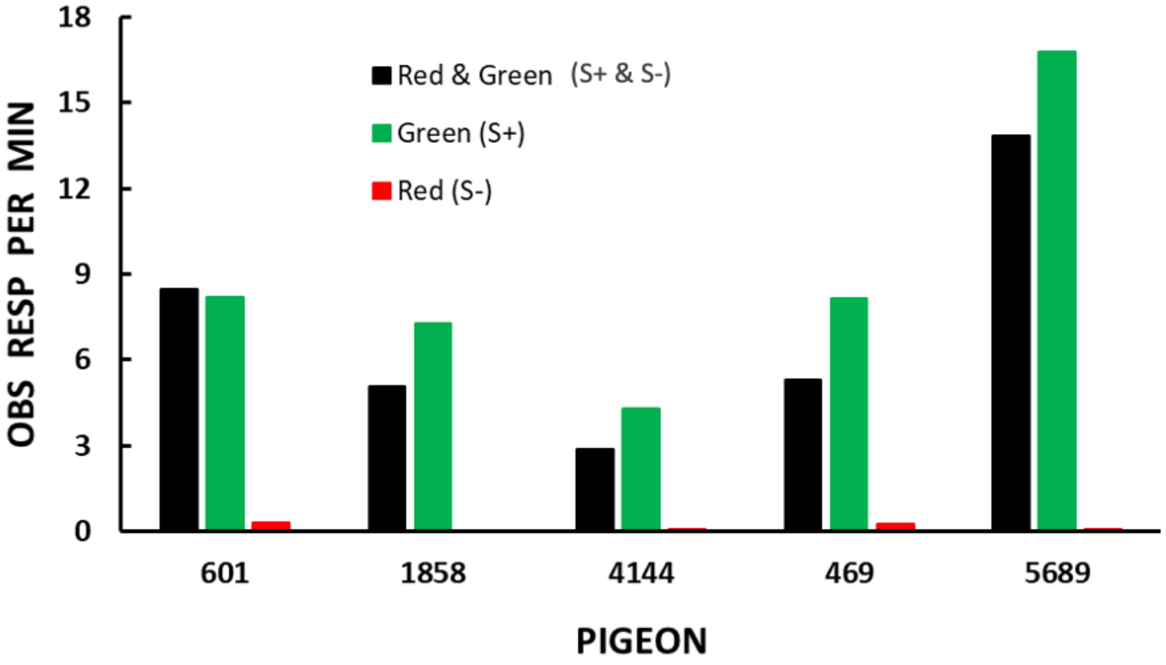
Rate of Reinforcement in the Presence of Each Stimulus Across Reinforcer Durations in the Observing Conditions

					Stimulus			
	Stimuli Available		# of	Food	S+	S1	S2	Mix
Pigeon	Left	Right	Sessions	Dur (s)	Food Reinforcers Per Minute			
1108	S+/S-	S1/S2	28	3	1.18 (0.15)	0.07 (0.14)	0.49 (0.46)	0.43 (0.03)
	S1/S2	S+/S-	21	3	1.47 (0.20)	0.69 (0.65)	0.23 (0.46)	0.29 (0.08)
	S+	S1	33	3	1.14 (0.28)	0.43 (0.24)	−−	0.28 (0.03)
	S1	S+	20	4	0.90 (0.07)	0.00 (0.00)	−−	0.36 (0.05)
	S+	S1	23	4	0.92 (0.16)	0.59 (1.18)	−−	0.37 (0.03)
	S+/S-	S1/S2	18	4	0.93 (0.14)	0.44 (0.30)	0.31 (0.38)	0.47 (0.03)
	S-	S2	20	4	−−	−−	0.00 (0.00)	0.53 (0.05)
	S2	S-	21	4	−−	−−	0.33 (0.43)	0.47 (0.06)
	S1/S2	S+/S-	23	4	0.92 (0.18)	0.18 (0.36)	0.50 (1.00)	0.49 (0.05)
88	S+/S-	S1/S2	20	3	1.06 (0.42)	0.00 (0.00)	0.00 (0.00)	0.42 (0.07)
	S1/S2	S+/S-	20	3	0.00 (-)	0.00 (-)	0.66 (0.68)	0.49 (0.04)
	S1	S+	24	3	0.00 (-)	0.31 (0.39)	−−	0.45 (0.03)
	S+	S1	31	3	0.85 (0.49)	0.46 (0.71)	−−	0.42 (0.05)
	S+	S1	21	4	1.11 (0.14)	1.16 (1.16)	−−	0.36 (0.03)
	S1	S+	13	4	6.93 (3.18)	0.20 (0.26)	−−	0.43 (0.03)
	S+/S-	S1/S2	18	4	0.98 (0.25)	2.31 (-)	−−	0.46 (0.07)
	S-	S2	20	4	−−	−−	2.31 (-)	0.51 (0.03)
90	S1/S2	S+/S-	26	3	0.95 (0.30)	0.00 (0.00)	0.31 (0.62)	0.46 (0.05)
	S+/S-	S1/S2	10	3	0.93 (0.28)	0.00 (0.00)	1.40 (2.36)	0.42 (0.06)
	S1/S2	S+/S-	22	4	0.64 (0.16)	0.00 (-)	0.00 (-)	0.39 (0.08)
	S+/S-	S1/S2	10	4	−−	0.00 (-)	0.54 (0.54)	0.38 (0.03)
	S1	S+	29	4	0.67 (0.18)	0.00 (-)	−−	0.12 (0.05)

Note. Food reinforcement rates are shown as means with standard deviations in parentheses. The conditions are shown in order of exposure. The number (#) of sessions and food duration in seconds are shown for each condition.

Figure 1

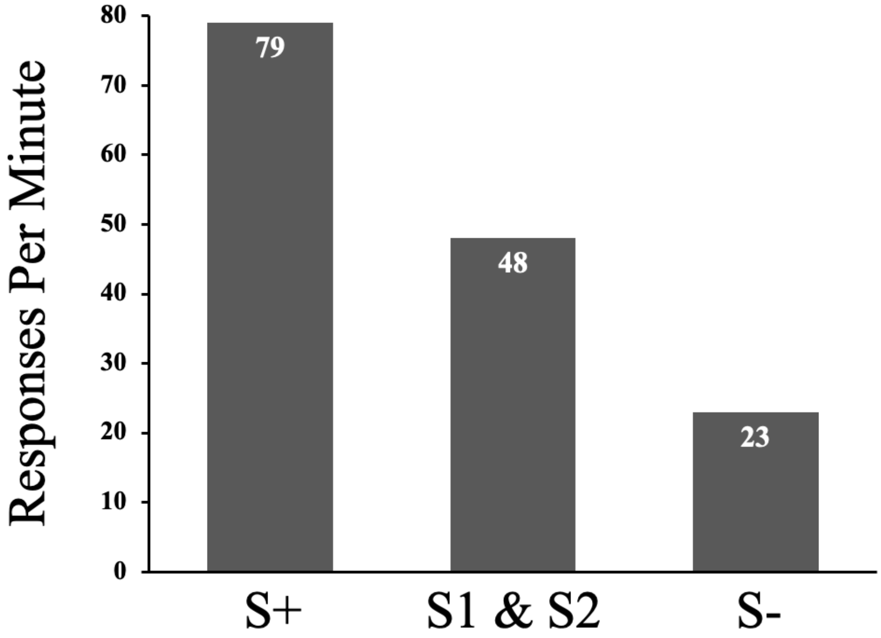
Observing Response Rates in Relation to the Stimuli Produced by the Response.



Note. "OBS RESP" = "Observing Responses." The figure is based on the steady-state data in Table 1 of Dinsmoor, Brown, and Lawrence (1972).

Figure 2

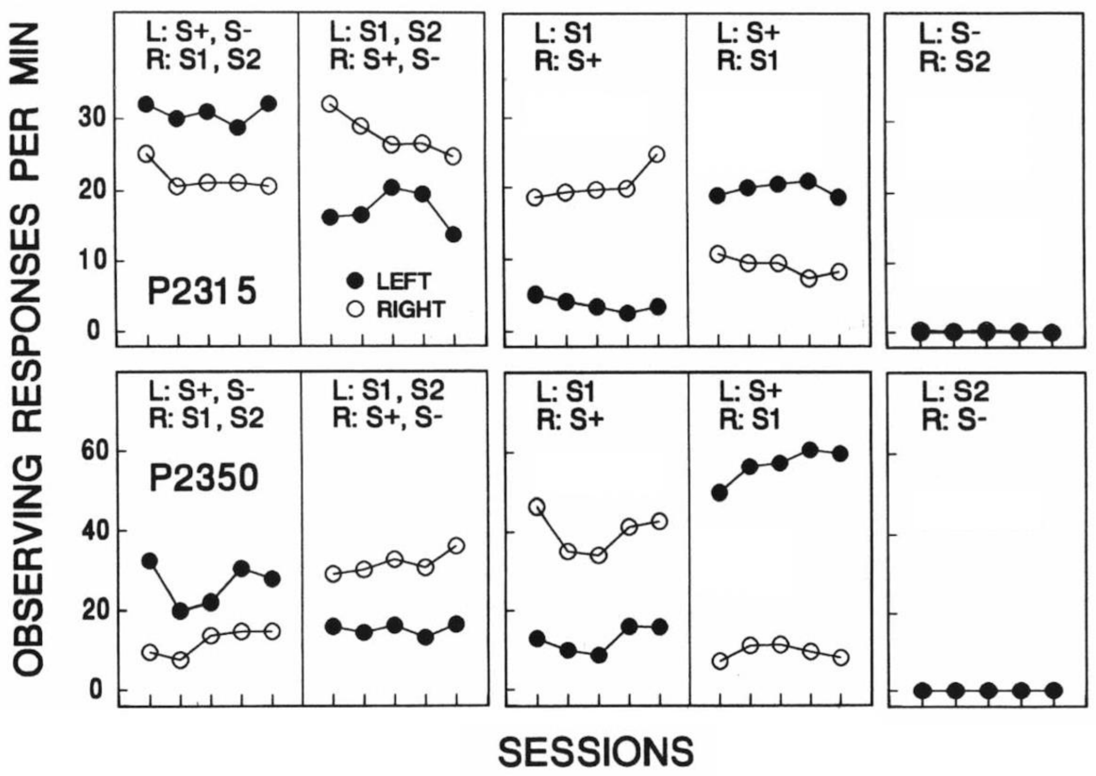
Observing Response Rates on Levers to Produce S+, S1, S2, and S-.



Note. The figure is based on data in Table 1 of Fantino and Case (1983, Experiments 1 and 2). Each bar shows the mean responses per minute in the presence of S+, S1 and S2, and S- for the 14 students that participated in either experiment.

Figure 3

Observing Response Rates in a Comparison Between Correlated and Uncorrelated Stimuli



Note. Results are from the last five sessions of each condition for Pigeons P2515 and P2350. The stimuli available on the left (L) and right (R) observing keys are shown at the top of each panel.

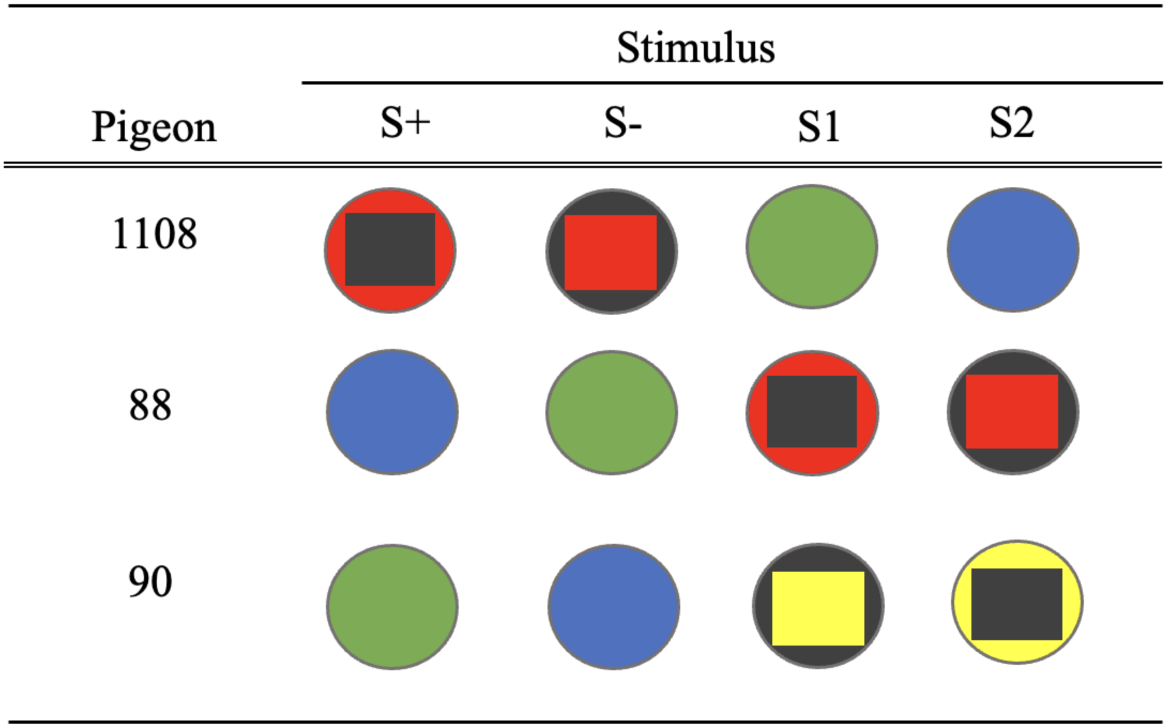
Figure 4

Front Panel of the Pigeon Chamber.

Note. A touchscreen is held to the front panel by a metal faceplate. The six circular openings in the faceplate permit visual and physical access to the touchscreen. When an accessible area is lit with a color or a geometric stimulus, it becomes a response key.

Figure 5

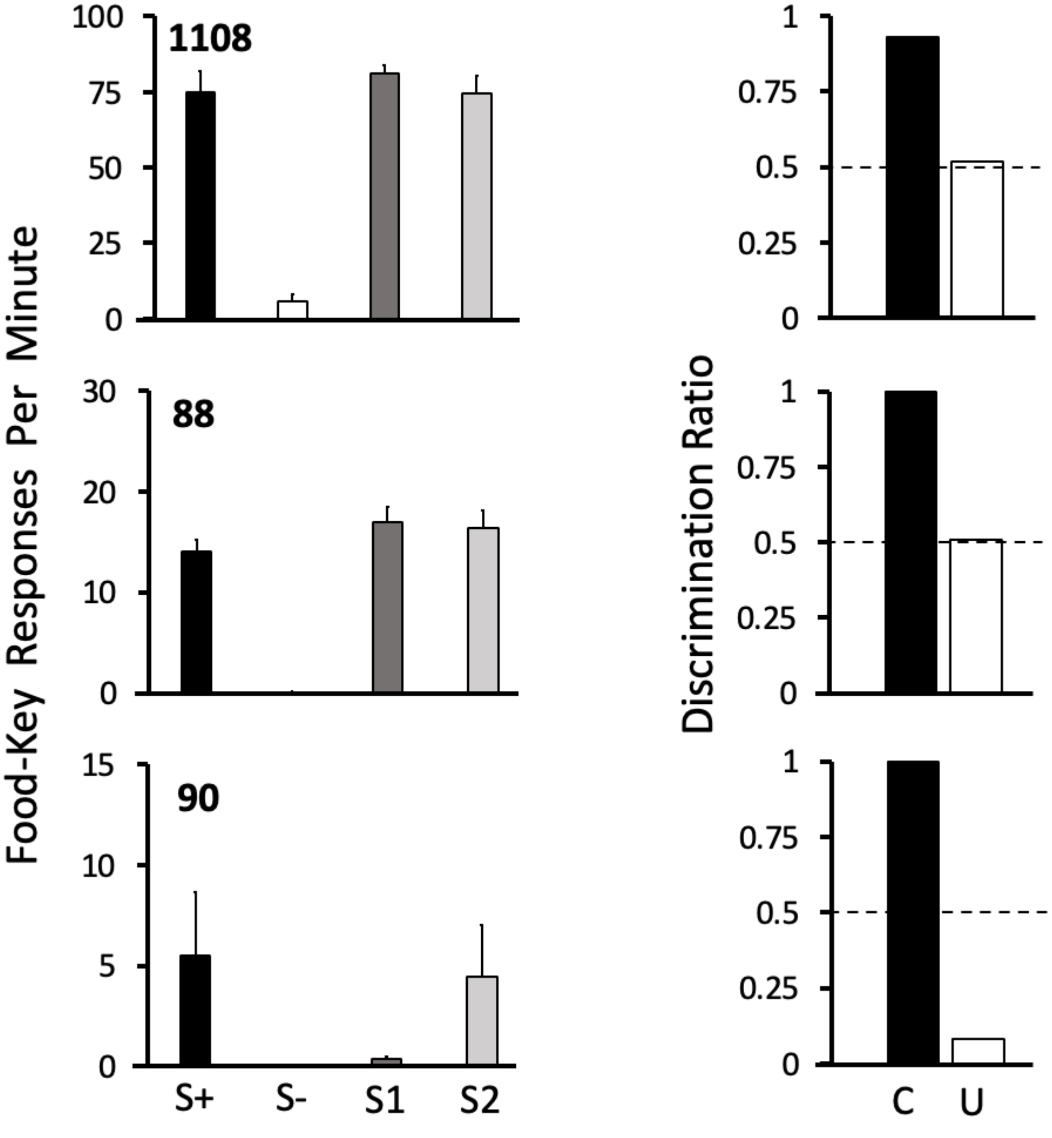
Schedule-Correlated and Uncorrelated Stimuli



Note. S+ and S- are correlated with the irregularly alternating VI 60-s and EXT components on the food key. S1 and S2 are uncorrelated with the components. The mixed stimulus, not displayed in the figure, was white.

Figure 6

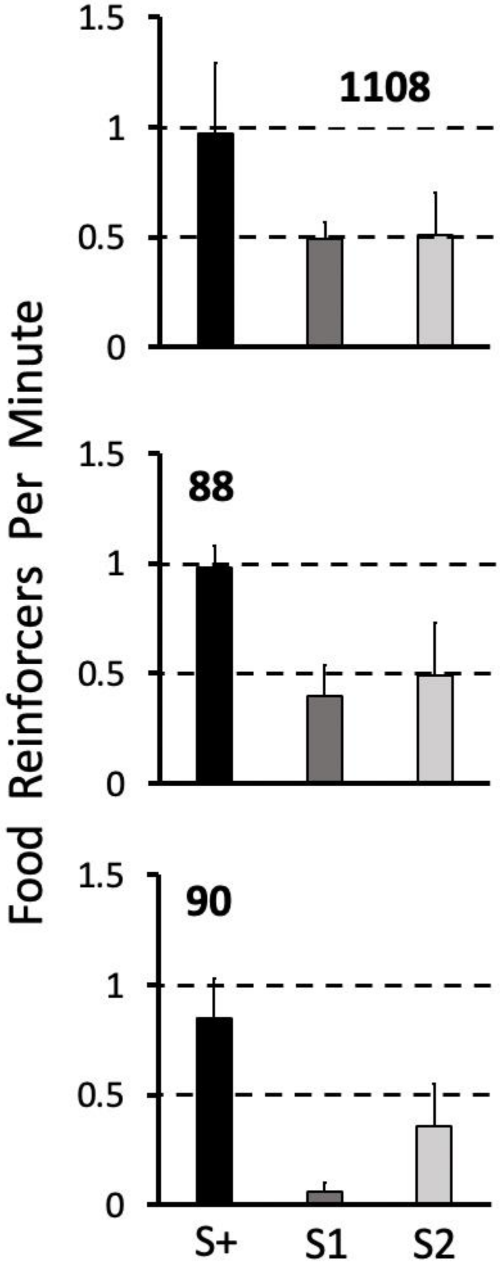
Food-Key Response Rates and Discrimination Ratios During Discrimination Training



Note. Mean food-key responses per minute in the stable five sessions of discrimination training (left column). Correlated (C) and Uncorrelated (U) discrimination ratios (right column). Error bars in the left column extend one standard deviation above the mean.

Figure 7

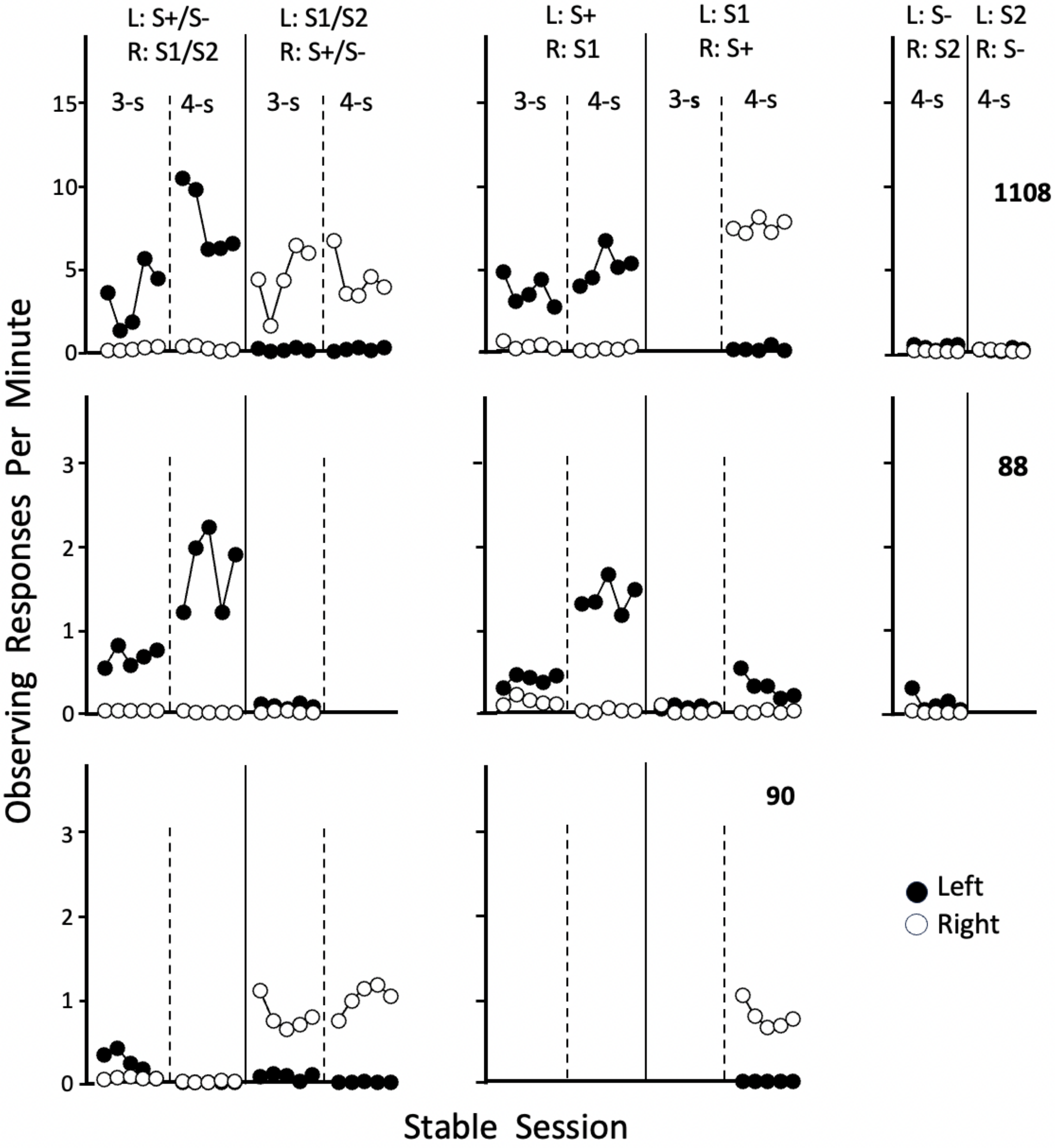
Rate of Reinforcement During Discrimination Training



Note. Mean food reinforcers per minute in the stable five sessions of Discrimination Training. Error bars extend one standard deviation above the mean. The horizontal dashed lines show the programmed rate of food reinforcement in the presence of S+ (1.0) and S1 and S2 (0.5).

Figure 8

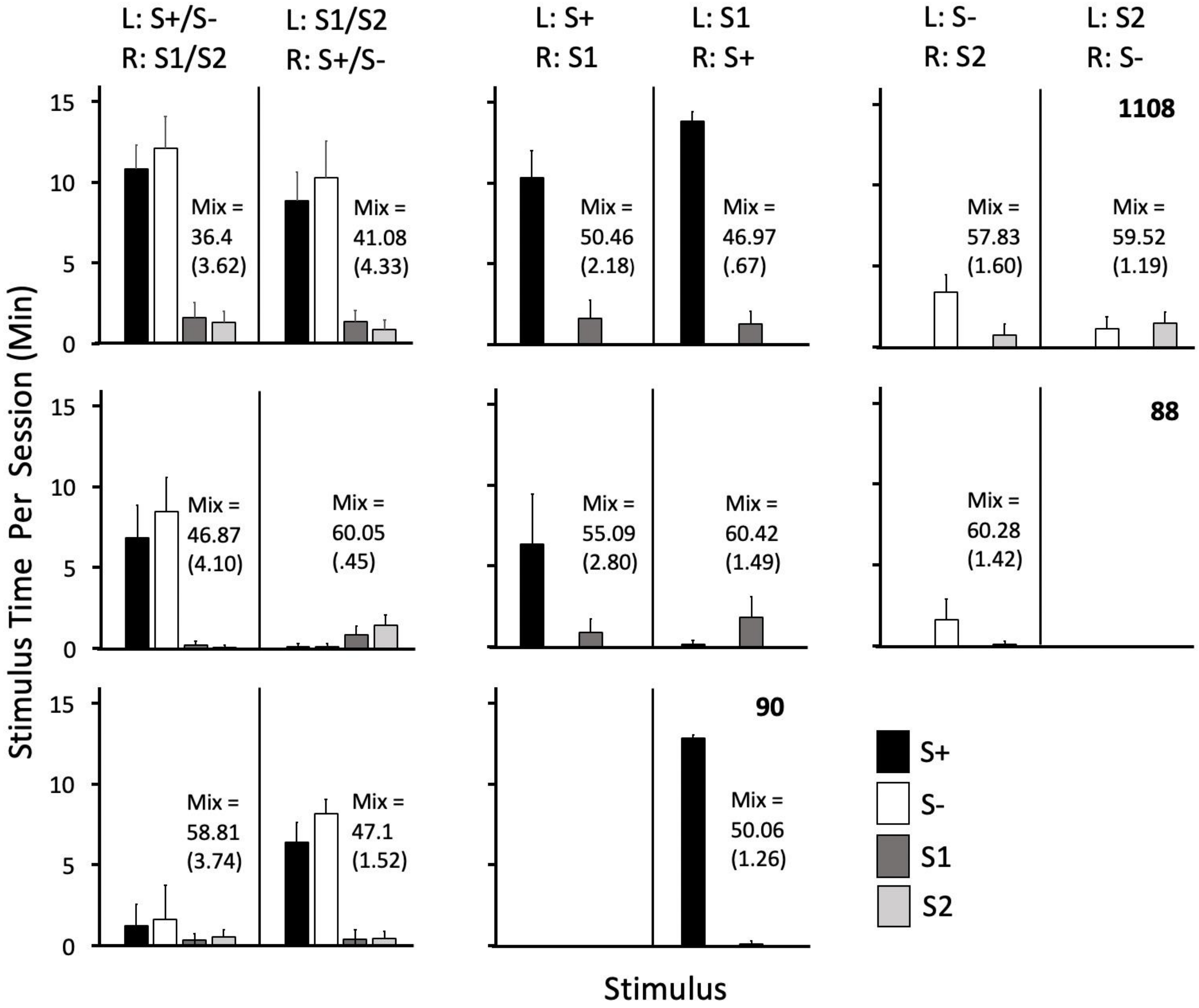
Absolute Observing Response Rates Across Conditions



Note. Mean observing responses per minute on the left and right observing keys in the stable five sessions of each observing condition. The reinforcer duration (3-s *vs.* 4-s) is shown in each panel. The labels above each column show the stimuli produced by the left (L) and right (R) observing keys.

Figure 9

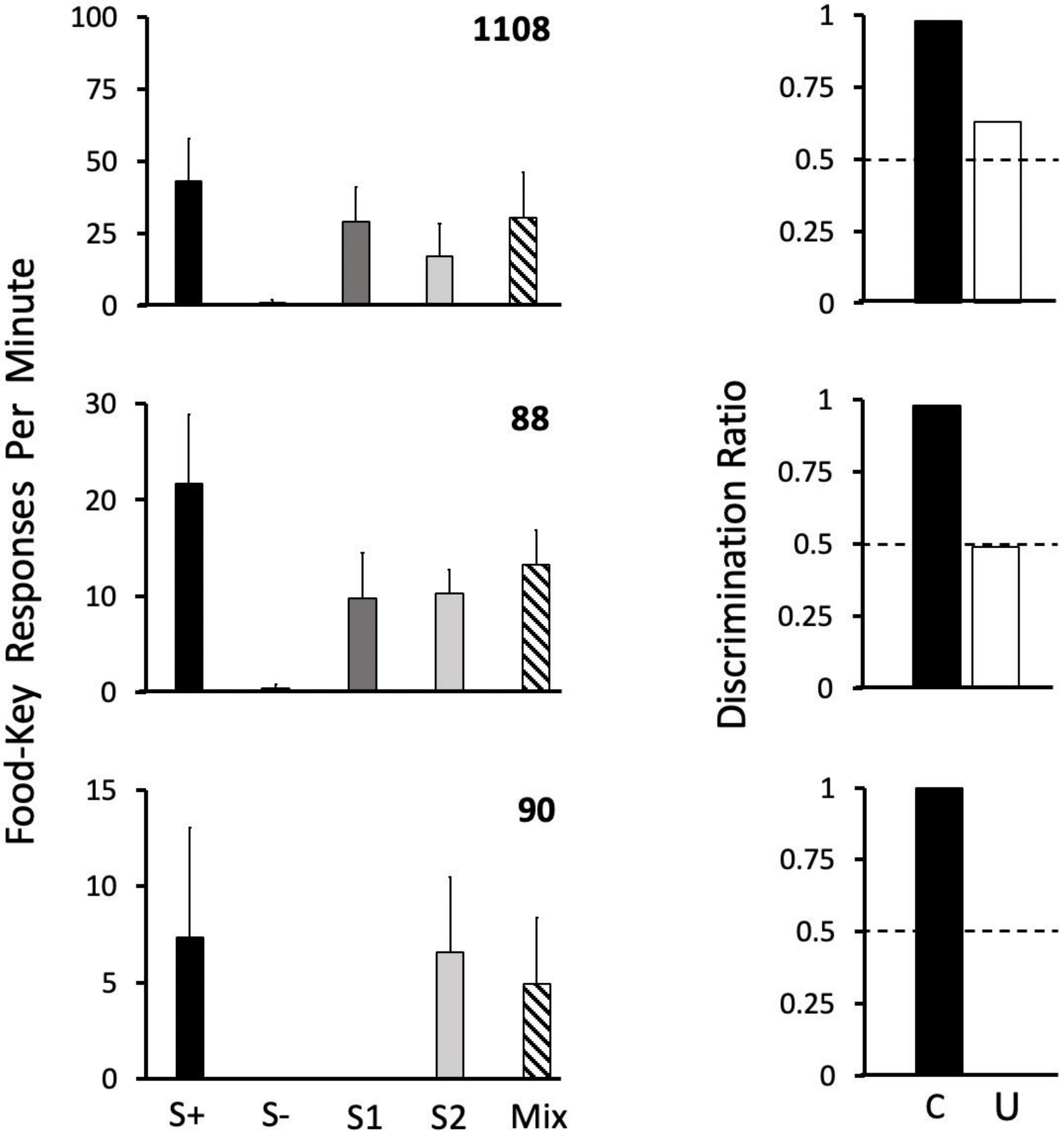
Time Spent in Each Stimulus Per Session Across the Observing Conditions



Note. Mean number of minutes per session spent in the presence of each stimulus in the five stable sessions of each observing condition. The results collapse across comparisons of the 3-s and 4-s food reinforcer durations. The duration of time spent in the mixed stimulus is displayed in text with the standard deviation in parentheses. Error bars extend one standard deviation above the mean. The labels above each column show the stimuli produced by the left (L) and right (R) observing keys.

Figure 10

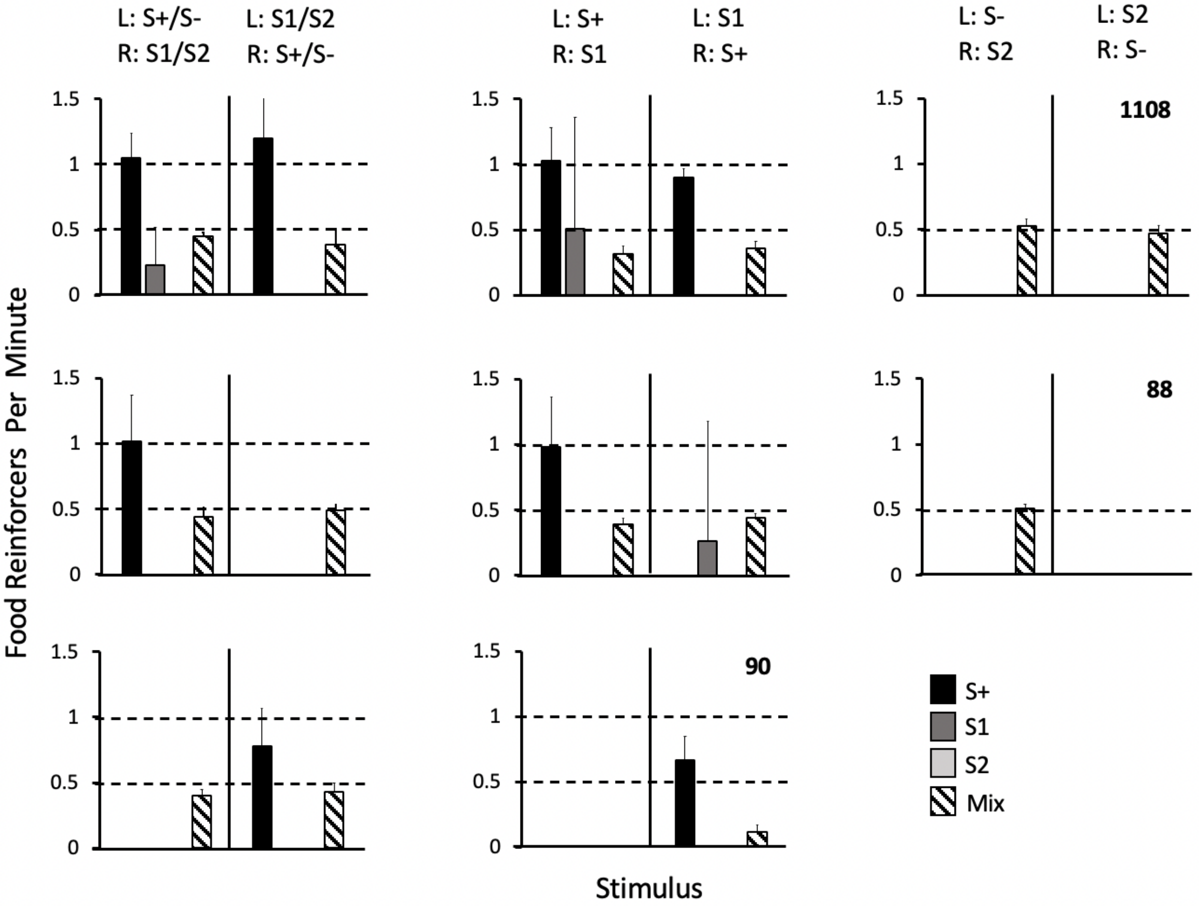
Food-Key Response Rate and Discrimination Ratios During the Observing Conditions



Note. Mean food-key responses per minute, collapsed across observing conditions (left column). Correlated (C) and Uncorrelated (U) discrimination ratios (right column). Error bars in the left column extend one standard deviation above the mean.

Figure 11

Rate of Food Reinforcement Across the Observing Conditions



Note. Mean reinforcers per minute in the presence of each stimulus in the five stable sessions of each observing condition. The results collapse across comparisons of the 3- and 4-s reinforcer durations. Error bars extend one standard deviation above the mean. The labels above each column show the stimuli produced by the left (L) and right (R) observing keys. The horizontal dashed lines show the programmed rate of food reinforcement in the presence of S+ (1.0) and S1 and S2 (0.5).