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Is extinction the hallmark of operant discrimination?:

Reinforcement and S^A effects

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Abstract

Using a successive discrimination procedure with rats, three experiments investigated the contribution of reinforcement rate and amount of S^A exposure on the acquisition of an operant discrimination. S^D components were always 2 min in length, while S^A (extinction) components were either 1 min or 4 min in length; responses in S^D were reinforced on one of four schedules. In Experiment 1, each of eight groups were exposed to one possible combination of rate of reinforcement and S^A component length. At every level of reinforcement, the 4 min S^A groups acquired the discrimination more quickly. However, within each level of reinforcement, the proportions of responding in S^D as a function cumulative S^A exposure were equivalent, regardless of the number of reinforcers earned in S^D, suggesting that extinction is the “hallmark” of discrimination. Experiment 2 sought to replicate these results in a within-subjects design, and although the 4 min S^A conditions always produced superior discriminations, the lack of discriminated responding in some conditions suggested that stimulus disparity was reduced. Experiment 3 clarified those results and extended the finding that the acquisition of operant discrimination closely parallels extinction of responding in S^A. In sum, it appears that higher reinforcement rates and longer S^A exposure facilitate the acquisition of discriminated operant responding.

Keywords

Stimulus control; Rate of reinforcement; S^A component length; Lever-press; Rat

1. Introduction

When changes in behavior are a function of changes in antecedent stimuli, stimulus control is said to exist (Eckerman, 1969; Mackintosh, 1977; Rilling, 1977; Terrace, 1966). In the broad psychological community, stimulus control has received a great deal of interest, both experimentally and theoretically. Indeed, Pavlov’s *Conditioned Reflexes* (Pavlov, 1960) can be seen as largely a study of conditional stimulus control of reflexes (Dinsmoor, 1995). With Skinner’s distinction between two types of conditioning procedures, Type S and Type R, and the recognition that antecedent stimuli appear to control both classically and operantly conditioned responses, the distinction between Pavlovian and operant stimulus control became a major focus of learning theory, especially in stimulus–response (S–R) accounts of learning and behavior. But Skinner explicitly rejected S–R theories and some have argued that this shifted the focus of the experimental analysis of operant behavior to the control of behavior by consequences (Dinsmoor, 1995).

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However, stimulus control of operant behavior is ubiquitous, both in the laboratory and outside and thus of great import to the experimental analysis of behavior. Davison and Nevin (1999) recently asserted that the discriminated operant is the fundamental unit of the experimental analysis of behavior, shifting some of the emphasis on consequential control of behavior back to antecedent stimuli. Skinner also recognized its ubiquity by noting that after initial operant conditioning “discriminative stimuli are practically inevitable” (Skinner, 1972), and conducted some of the first experiments on operant stimulus control using an elegant methodology to study it: the successive discrimination procedure. In this preparation, two stimuli are presented in an experimental chamber; responses in the presence of one stimulus (an S^D or S^+) produce reinforcers, whereas responses in the presence of the other stimulus (S^A or S^-) do not. This multiple reinforcement-extinction schedule cycle is repeated many times per session. Because of the simplicity of the procedure and the myriad of variables that can be manipulated within it, the successive discrimination procedure remains the standard preparation for establishing operant stimulus control. However, while the successive discrimination procedure has been widely used to establish stimulus control, little research has been conducted on the variables that affect the rate of that establishment, or the acquisition of a discrimination, as opposed to the variables that affect stimulus control, once established.

Following Skinner’s lead, Keller and Schoenfeld (1950) claimed that because the initial shaping of an operant was easier than subsequent extinction, and that stimulus control implied both increases in correct responding (e.g., S^D) and decreases in incorrect responding (S^A), that extinction was the “hallmark” of discrimination. Similarly, Jenkins argued that responding in the presence of a stimulus was not evidence of stimulus control, but that control was a “synonym for covariation” (Jenkins, 1965). Keller and Schoenfeld affirmatively answered the question of whether or not extinction of S^A responding was required for the establishment of stimulus control, even though they provided no data for this conclusion. Dinsmoor challenged this conclusion because stimulus control has been demonstrated after non-differential reinforcement, errorless discrimination learning (Terrace, 1963), or very early in training, prior to exposure to any extinction conditions (Dinsmoor, 1995). However, even though extinction of responding in S^A may not be required, Dinsmoor said nothing about the absence of responding in S^A , which may result from extinction or some other process.

Two variables, stimulus disparity and stimulus salience, have received the greatest amount of interest in the study of operant stimulus control. A third variable, rate of reinforcement in S^D , has received surprisingly little attention in the study of the establishment of stimulus control. Generally, higher reinforcer rates produce steeper generalization gradients (Eckerman, 1969; Hearst et al., 1964), however little is known about the acquisition phase. In Eckerman’s (1969) study, she found that during discrimination training, S^D responding remained fairly constant, while S^A responding declined to near zero rates, thereby suggesting that amount of exposure to S^A may be a fourth, important, independent variable. For example, Eckerman noted that extinction of responding in S^A was invariant to the number of reinforcers in S^D , regardless of the probability or rate of reinforcement in S^D . In her study, roughly 25 cumulative reinforcers were required in the presence of S^D to fully extinguish S^A responding. However, because the probability of reinforcement in S^D varied across groups, some rats had six times (the 0.16 probability of reinforcement group) as many trials as other rats (the 1.0 probability of reinforcement group). In a similar vein, Sherman et al. (1964) showed that changes in discrimination indexes were largely a function of cumulative time in S^A . Taken together, Eckerman (1969) and Sherman et al. (1964) provide support for the contention that extinction is the hallmark of discrimination.

A similar invariant relation between cumulative reinforcers and discrimination has been demonstrated by Williams (1989), albeit with a different procedure and different measures. In that study, Williams showed that discrimination ratios, in contrast to S^A responding, were

invariant to the number of obtained reinforcers in S^D , irrespective of the programmed reinforcement probability. Williams' "invariance hypothesis" could account for the results of Hearst et al. (1964) and Eckerman (1969) because although rate of reinforcement was controlled, the number of reinforcers was not. However, in both Eckerman's and William's studies the amount of time in S^D varied with reinforcement probability, leading Eckerman to conclude that "research varying both the probability of reinforcement during the positive stimulus and the amount of exposure to the negative stimulus would help determine the effects of the probability of reinforcement itself" (1969, p. 558).

Therefore, given the importance of stimulus control in the experimental analysis of behavior, it is surprising that the acquisition period has received scant interest and appears to be an important topic to study. The present experiments focused on the acquisition or repeated acquisition of an operant discrimination, while varying the rate of reinforcement and amount of exposure to S^D , as suggested by Eckerman (1969). The design allowed for assessment of the role of reinforcer rate and extinction of responding in S^D on the development of an operant discrimination.

2. Experiment 1

2.1. Methods and materials

2.1.1. Subjects—Forty-eight experimentally naïve male Long-Evans hooded rats obtained from Charles River (eight groups of six rats) were approximately 150 days of age (400–450 g) at the beginning of the experiment and were maintained at 80% of their free-feeding weights by supplemental feedings after experimental sessions with standard rat chow. Rats were individually housed in standard stainless-steel cages with free access to water in a room with a 12:12 h light/dark cycle.

2.1.2. Apparatus—Sessions were conducted in 12 commercially constructed operant chambers (Gerbrands, approximately 310 mm wide × 330 mm deep × 300 mm high) enclosed in sound-attenuating, ventilated chests. Fans provided some masking noise continuously throughout sessions. The chamber walls and ceiling were constructed of aluminum and the floor rods (spaced 20 mm apart) were stainless steel. A 28-V houselight was mounted in the center of the ceiling. Located on the back wall were two levers, 50 mm wide, 115 mm apart and 50 mm above the grid floor. A force of at least 0.20 N was necessary to operate the lever. Two pairs of stimulus lights were located 45 mm above each lever, red on left and white on right. Only the right lever and white lights were used. An opening 45 mm square was located directly below, and spaced evenly between the two levers and contained a feeder tray into which 45 mg Bio-Serv[®] sucrose pellets could be delivered. Experimental events were arranged and recorded via a personal computer in an adjacent room running MED-PC for Windows software.

2.2 Procedure

Magazine training consisted of 3 days of RT-60 s schedule of pellet delivery with a conjoint FR-1 programmed on the right lever for 100 pellet deliveries. Lever-pressing was then reinforced on three successive days of FR-1 until 100 reinforcers (per day) were delivered (without the RT schedule). All rats made at least 100 responses by the third day of FR-1, even though no explicit shaping was conducted (e.g., via reinforcement of successive approximations). Rats were matched with respect to their response rates during the last day of shaping. Group assignment was accomplished by taking the eight rats with the highest rates of responding and randomly assigning individuals to one of the eight different conditions. The next eight highest responders were randomly assigned in the same fashion. The next eight were assigned the same way; this continued until all rats were assigned to one of the eight conditions.

This matching was completed so as to not bias the design with one condition having more rats with high, or low, baseline response rates. The houselight remained on during all sessions, but the stimulus lights (above each lever) were not illuminated during magazine or lever-press training. Sessions were run 5–7 days per week, one session per day.

Following preliminary training, rats were exposed to a successive discrimination procedure, that is, a two-component multiple schedule for 10 cycles each session (10 S^D components and 10 S^A components). Each session began with an S^D component followed by an S^A component; components strictly alternated thereafter. S^D components lasted 2 min for every group. S^A components were 1 min for four of the groups, while S^A components lasted 4 min for the other four groups. Components were distinguished by the white stimulus lights just above the right lever (lights on = S^D , lights off = S^A). Preliminary experiments (not shown) investigated the influence of the stimulus type (lights on/off) as S^D and found no effect, thus all subjects received lights on as S^D and lights off as S^A . In the presence of the stimulus lights responses were reinforced on one of four schedules, an RI-10 s, RI-30 s, RI-60 s, or RI-90 s. The amount of S^A exposure and rate of reinforcement served as the two factors in this experiment, yielding a $2 (S^A \text{ length}) \times 4 (\text{programmed reinforcement rate})$ design with eight groups. Rats were exposed to 40 sessions of discrimination training.

Analyses were conducted upon two indexes of discrimination. The first, termed the unbiased discrimination ratio (“UDR”), was computed, for individual rats, from their response rates in S^D and their response rates during the first minute of S^A , regardless of group assignment. This measure avoided the potential problem that groups exposed to 4 min extinction components might show within-component decrements in S^A responding. Decreases in responding during minutes 2–4 of S^A /extinction may lower the overall rate of responding in S^A thereby increasing a discrimination index. The second index, the proportion of responding in S^D (“Prop Resp in S^D ”), included all the responses in a session and was computed by dividing the mean number of responses per minute in S^D by the sum of the mean number of responses per minute in S^D plus the mean number of responses per minute in S^A . Between-group comparisons, within each level of reinforcement, were conducted using two way repeated-measures ANOVA with S^A length and blocks of sessions as factors. Post hoc pairwise comparisons were conducted using Tukey’s HSD test, including comparisons following significant interactions (Paulson, 2003).

2.3. Results

Mean unbiased discrimination ratios (UDR) per group per blocks of five sessions are plotted in Fig. 1. Acquisition curves for individual rats in each of the eight conditions across sessions are inset in the figures.

As can be seen from Fig. 1, the groups with 4 min S^A components reached asymptotic levels of stimulus control more quickly when compared to the groups with 1 min S^A components (open symbols versus filled symbols), at every level of reinforcement. This was the case even after removing the influence of responding during minutes 2–4 of extinction for rats exposed to 4 min S^A periods. Separate two-way repeated-measures ANOVA on the UDR within each level of reinforcement were conducted with S^A length and blocks of sessions as factors. The main effect of S^A length was significant in the RI-30 s, RI-60 s, and RI-90 s groups, but not in the RI-10 s groups. The main effect of blocks of sessions was highly reliable across all levels of reinforcement (all $p < .001$). Most importantly, though, the ANOVAs revealed statistically reliable S^A length $\times$ blocks of sessions interactions at each level of reinforcement (F ’s = 4.165, 12.857, 15.504, and 7.666, respectively). Post hoc analyses comparing group means within each five-session block revealed many statistically significant between-group differences, which are shaded with a gray box in Fig. 1. For example, in comparing the RI-10 s groups, the mean UDR for the 4 min S^A group was higher than the 1 min S^A group for the first blocks of five sessions, but not statistically differentiated after. In addition, UDRs were not differentiated

within each of the four levels of rate of reinforcement by the eighth block of sessions, which suggests that comparable levels of stimulus control were reached between the 1 min and 4 min S^A groups within a particular level of reinforcement.

Because the number of reinforcers delivered during the S^D components were nearly equivalent for the two groups within each level of reinforcement (no statistically reliable differences were found), acquisition curves as a function of obtained reinforcers were nearly identical to those presented in Fig. 1. Therefore, the invariance hypothesis of Williams (1989) was contradicted within each level of reinforcement, although no predictions about acquisition within the S^A length level were made. In other words, it is possible that the four 4 min S^A groups (or the four 1 min S^A groups) might acquire the discrimination as a function of cumulative reinforcers at a similar rate, regardless of the program rate of reinforcement in S^D . Fig. 2 re-plots the UDRs in Fig. 1 as a function of cumulative reinforcers for each S^A length.

Interestingly, Fig. 2 appears to show that the lower reinforcement rate groups acquired the discrimination more rapidly. For example, in terms of cumulative reinforcers, the RI-90 s/1 min S^A group acquired the discrimination more rapidly than the RI-10 s/1 min S^A , an effect paralleled in the 4 min groups. However, in comparing the RI-10 s group with the RI-90 s group, the RI-90 s groups had been exposed to many more sessions, and hence more exposure to S^A . This was a direct consequence of the lower reinforcement rates; the RI-90 s groups required about nine times as many sessions as the RI-10 s groups to earn equivalent numbers of reinforcers. Nevertheless, the acquisition of a discrimination, in the present experiment, was not invariant to cumulative reinforcers, thereby contradicting the results of Williams (1989).

Because discrimination ratios are relative measures, they can change due to changes in either the numerator (e.g., responses in S^D) or responses in the denominator (e.g., responses in S^A). Therefore, Fig. 3 shows group mean response rates as a function of blocks of five sessions with S^D in the upper panels and S^A in the lower panels.

Although higher programmed rates of reinforcement produced higher S^D response rates, within each level of reinforcement, no statistical differences in S^D responding between 1 min and 4 min S^A groups were found. In contrast, extinction of S^A responding was clearly quicker in the 4 min groups than the 1 min groups, under each of the four levels of reinforcement and the variability in S^A response rates was less in the 4 min groups when compared to the 1 min groups.

While Fig. 1 shows that the 4 min groups acquired the discrimination more rapidly as a function of sessions than the 1 min groups, the 1 min S^A groups did reach comparable levels of stimulus control to the 4 min groups. In addition, Fig. 2 shows that acquisition was not invariant to cumulative reinforcers, while Fig. 3 indicates more rapid extinction of S^A when S^A components were 4 min. Fig. 4 re-plots the proportion of responding in S^D ("Prop Resp in S^D ") as a function of cumulative time in S^A , in a manner similar to the way Sherman et al. (1964) presented their data.

Repeated-measures ANOVA on each of the four comparisons presented in Fig. 4 revealed no differences. Generally, Fig. 4 shows that the acquisition of an operant discrimination is invariant to cumulative time in S^A . That is to say, the rate at which an operant discrimination is acquired, within each level of reinforcement, depends on the amount of time spent in extinction, rather than cumulative reinforcers earned because for each point plotted for the 4 min S^A groups, the point for the 1 min group represents four sessions. Given that the number of obtained reinforcers per session (and block) was roughly equivalent (within each level of programmed reinforcement), each point for the 1 min groups represents roughly four times as many reinforcers.

To assess the role of reinforcement rate on acquisition of an operant discrimination, the two curves in each of the four panels of Fig. 4 were collapsed together. The mean of each of the four different programmed reinforcement rate groups, as a function of cumulative S^A time is plotted in Fig. 5.

In Fig. 5, a clear effect of reinforcement rate is seen on the rate of acquisition of discrimination as a function of S^A time. The RI-10 s group curve, which represents all rats in the RI-10 s groups (1 min and 4 min), is steeper and reaches asymptote more quickly than the other three groups. Moreover, the steepness of the curves is in order with respect to the programmed rate of reinforcement. ANOVA confirms the results presented in Fig. 5. Namely, a main effect of schedule type ($F(3, 44) = 25.052, p < .001$) and interaction ($F(27, 396) = 6.853, p < .001$) were found. The main effect of cumulative S^A exposure ($F(9, 396) = 310.784, p < .001$) was expected: the Prop Resp in S^D increased as exposure to the extinction component increased. The main effect of schedule, and subsequent post hoc comparisons using Tukey's HSD revealed that overall, the RI-10 s group had a higher Prop Resp in S^D than the three other groups, that the RI-30 s had a higher Prop Resp in S^D than the RI-60 s and RI-90 s group, but the RI-60 s and RI-90 s were not statistically differentiated. The statistically reliable interaction suggests that the rate of change of Prop Resp in S^D over blocks of S^A exposure was different for the four groups, which also appears to be the case in Fig. 5.

2.4. Discussion

The present results strongly suggest that the acquisition of an operant discrimination, trained using a multiple reinforcement-extinction schedule, depends largely on extinction of S^A responding, and thereby time spent in the presence of S^A , irrespective of the number of responses, amount of time, or cumulative number of reinforcers earned in S^D . These results contradict those of Williams (1989) showing that the acquisition of a discrimination was invariant to obtained reinforcers, although other procedural differences may account for the discrepancy between the present results and those of Williams (1989). In the present experiment, at every level of programmed reinforcement, rats acquired the discrimination faster when exposed to 4 min S^A components. The invariance that was observed in the present experiment involved cumulative time spent in S^A , thereby replicating the experiment conducted by Sherman et al. (1964). In addition, as Eckerman (1969) suggested, by varying the amount of time in S^A , the role of reinforcement rate on the acquisition of discrimination might be determined. In the present results, while statistically controlling for the amount of S^A exposure, the rate of acquisition of discrimination was a direct function of rate of reinforcement, with RI-10 s producing the most rapid discrimination and RI-90 s producing the slowest. It should be noted, however, that while reinforcement rates in the S^D component were equal for both groups within each level of reinforcement (the obtained number of reinforcers per session was not statistically differentiated), the rates of reinforcement for the overall session were not identical, because the 4 min S^A groups had longer sessions (30 min longer). Moreover, higher rates of reinforcement also produce higher rates of responding, and unfortunately, the present experiment cannot assess the influence of response rate on acquisition of a discrimination. Haber and Kalish (1963) and Hearst et al. (1964) have demonstrated steeper generalization gradients with higher rates of programmed reinforcement, although the roles of cumulative reinforcers or response rates were not assessed in either study. In the present experiment, the differences in functions in Fig. 2 and the similarity of the functions presented in Fig. 4 suggest a limited role for obtained reinforcers.

This appears to be the first experiment manipulating S^A length, although others have suggested it, especially Eckerman (1969). Hearst (1962), while conducting seminal experiments on stimulus control reinforced with food versus shock-avoidance, noted that in one of the training conditions monkeys were exposed to S^A components that were three and five times as long as

the S^D components. This may suggest that a role for this variable was indicated in his pilot experiments, but no data were provided.

2.4.1. Limitations of the present experiment—There were several objectionable features to the design of Experiment 1 which require discussion or additional experimentation. First, the basis of the discrimination was presumably the exteroceptive stimulus changes provided by the experimenter, however, the discrimination and its development could have been due to the presence versus absence of reinforcers (sucrose pellets) themselves. Second, the components of the multiple schedules were fixed, thereby allowing for the possibility of a temporal discrimination to develop. Third, the S^D and S^A for all rats in the present experiment was the same (stimulus lights/no stimulus lights). Last, the experiment was conducted as a between-groups study that allows for the possibility that the differences observed were the result of chance; the fact that the n of each group was only six produces relatively low power for the statistical analyses.

The first concern is attenuated by the results of a previous experiment (Andrzejewski et al., 2004) that used a mixed schedule, with an FR-1 in the reinforcement component, to assess the role of reinforcer delivery as a discriminative stimulus. In that experiment, asymptotic discrimination ratios approached only .60, suggesting a very limited role for reinforcer delivery. It may be possible that by using probe trials during the session, in extinction, operant stimulus control could be more readily measured without the potentially confounding role of reinforcers. However, in the Andrzejewski et al. (2004) study, rates of reinforcement between-groups were also changing, thereby making it difficult to determine the role of reinforcers and delay, which was the primary variable being manipulated in that study. Although reinforcement rate over the entire session was not equal, at any given schedule value, the rate of reinforcement in S^D was roughly equal. Thus, it could be argued that any potential influence of reinforcer delivery in S^D on operant stimulus control was equal, as well. In contrast, the absence of reinforcers in S^A was not equal across groups; rats in the 4-min groups had longer exposure to no reinforcers in S^A , but that was the major independent variable in the present experiment. The second criticism could be addressed by varying the length of the components, as suggested by Davison and Nevin (1999) and Leslie (1996). However, in a direct test of the hypothesis that fixed-length components, as opposed to variable length components in a multiple schedule, accelerate the acquisition of an operant discrimination found limited support in Andrzejewski et al. (2004), although further experimentation was suggested. The third concern, that the stimuli for all rats in Experiment 1 were the same, contradicts sound experimental practice and design. Nevertheless, our experience (Andrzejewski, Morgan and Bersh, unpublished observations) indicates that counterbalancing stimulus type has no effect on acquisition or terminal level of an operant discrimination with equal length components, when responses are continuously reinforced in S^D . In addition, any beneficial effect of the stimulus type would presumably appear in all groups in the present experiment; the between-groups differences could not be attributed to differences in stimulus type, because all groups had the stimulus lights on as S^D and stimulus lights off as S^A , but only to an interaction between S^A length and stimulus type, which seems unlikely. One could suppose that the stimulus lights had some unspecified unconditional evocative or elicitive effect, but unlike other species (e.g., pigeons), rats are very active in the dark, possibly more than when the light is off. The last concern regarding the present experiment, that the study was designed and conducted as a between-groups experiment, reflects the bias that when acquisitions of new discriminations are studied, between-groups designs seem the most practical, even though a within-subjects design might be preferred.

3. Experiment 2

Experiment 2 addressed several of these concerns while using within-subjects designs. In a first squad of rats, S^d length was manipulated across three conditions, at two different programmed levels of reinforcement. In a second squad, the component type was varied across three conditions, with individual rats receiving either fixed-length or variable-length components.

3.1. Materials and methods

3.1.1. Subjects—Sixteen male Sprague–Dawley rats, obtained from Harlan breeders, were approximately 120–150 days of age at the beginning of the experiment and were maintained at 80% of their free-feeding weights by supplemental feedings after experimental sessions with standard rat chow. They were housed in pairs in polyethylene cages with free access to water in a room with a 12:12 h light/dark cycle. They had previous experience in an experiment investigating the acquisition of lever-pressing for sucrose pellets or chocolate milk, but not under food restriction. They had 10–15 sessions of FR-1 in this pilot experiment. By the end of this pilot experiment, all 16 rats were lever-pressing. This previous history seemed inconsequential to the repeated acquisition of an operant discrimination. Unpublished observations indicate that the different strains (e.g., Long-Evans versus Sprague–Dawley) acquire an operant discrimination equally well, however recent experiments have demonstrated strain differences with respect to visual acuity (Prusky et al., 2002). Nonetheless, because the design of the present experiment utilized a within-subjects methodology, comparisons between the present experiment and Experiment 1 will be limited, thus attenuating the issue of visual acuity and rat strain.

3.1.2. Apparatus—Sessions were conducted in eight commercially constructed operant chambers (Coulbourn, approximately 29 cm × 29 cm × 24 cm) enclosed in sound attenuating, ventilated chests. Fans provided some masking noise continuously throughout the session. The two sidewalls were constructed of aluminum, while the front and back walls were constructed of plexiglass. Two levers, approximately 3.5 cm apart, projected into the chamber on the right-side wall. Above the two levers, in the middle of the right wall, were a row of three stimulus lights (red, green and yellow LEDs) and a houselight. Spaced equally between the two levers was a feeder tray into which 45 mg Bio-Serv[®] sucrose pellets could be delivered. Experimental events were arranged and recorded via a personal computer in the same room as the chambers, running Graphic State Notation[™] (version 1.013-00), interfaced with L91-04S Habitest Universal Lincs (Coulbourn Instruments, Allentown, PA).

3.2. Procedure

Even though all 16 rats were already conditioned to lever-press, they received identical preliminary training to Experiment 1. The first three preliminary training sessions entailed extension of the right lever with responses reinforced on an FR-1 schedule (no lights were on during preliminary training). A conjoint RT-60 s schedule of sucrose pellet delivery was also operative. The next three sessions were an FR-1 on the right lever for 100 reinforcers, without the conjoint RT schedule. All rats were then transitioned directly into the experiment. Sessions were run 5–7 days per week, one session per day.

The procedure was similar to that of Experiment 1. A multiple schedule arrangement was used: each session began with the onset of the S^D , followed by S^d , followed by S^D , etc. Responses in the presence of the S^D were reinforced, and not reinforced (extinguished) in the presence of the S^d . S^d component length, like in the first experiment, varied, but rats were exposed to both values (1 min and 4 min) in a within-subject fashion. The “component type” was also manipulated and was either fixed (“F”) or variable (“V”) in length. Reinforcement (S^D)

components were always 2 min, or an average of 2 min (S^D component lengths in the V conditions were randomly selected without replacement from the list: 15 s, 40 s, 65 s, 90 s, 115 s, 125 s, 150 s, 175 s, 200 s, 225 s). S^A components were either 1 min or 4 min, and either fixed or variable in length (selected in V conditions without replacement; 1 min variable component list: 15 s, 25 s, 35 s, 45 s, 55 s, 65 s, 75 s, 85 s, 95 s, 105 s; 4 min variable component list: 15 s, 65 s, 115 s, 165 s, 215 s, 265 s, 315 s, 365 s, 415 s, 465 s). If the length of the reinforcement component varied, so did the length of the extinction component, but if the S^D component was fixed, the S^A component was fixed; component type was not mixed. In addition, the S^D and S^A were counterbalanced across rats, and were the houselight and flashing houselight (on 0.25 s, off 0.25 s) in condition 1. The S^D and S^A in condition 2 were counterbalanced, as well, and were the illumination of the row of LEDs and flashing LEDs (on 0.25 s, off 0.25 s). Condition 3 utilized the same S^D and S^A as in condition 1 because, as will be seen in the results, it appeared that the LEDs/flashing LEDs proved to be a challenging discrimination. The S^D and S^A were pseudo-randomly assigned, such that some rats received a consistent flashing versus non-flashing modality from condition 1 to 2 to 3, but others received different treatment. Lastly, in order to replicate some of the findings of Experiment 1, two different schedules of reinforcement were used, RI-30 s and RI-60 s. The design of the experiment and the order of conditions are presented in Table 1.

The conditions of the first squad of eight rats (S01–S08) were arranged to primarily assess the role of S^A length and reinforcement schedule; all components were fixed in length for these eight rats. The conditions of the second squad of eight (S09–S16) were designed to primarily test the effects of component type (fixed versus variable), however when this variable proved to have little influence, these eight rats were used to assess the role of component length on an operant discrimination.

Each condition was run for 25 sessions. The main dependent measure was the proportion of total responses that occurred in S^D ; total responses included all responses during S^A . This computation of proportion (in contrast to UDR in Experiment 1) was necessitated by the fact that in some cases, the length of the S^D and S^A periods were variable. As can be seen from Table 1, the design of Experiment 2 allowed for a number of within-subject and between-subject comparisons. For example, the effect of component length on an operant discrimination could be assessed in a within-subject fashion in 12 of the 16 rats (note that S11–S14 were only exposed to one level of the component length factor). The component type factor could also be assessed within-subject in the second squad of rats, especially in the first two conditions because other factors were held constant. Between-groups comparisons include the rate of reinforcement manipulated in the first squad of rats.

3.3. Results

The mean Prop of Resp in S^D as a function of blocks of five sessions for individual rats are plotted in the leftmost panels of Fig. 6. The three panels on the right side of Fig. 6 show the means of the combinations of levels of the three factors (S^D length, component type, and rate of reinforcement) for the three conditions.

As can be seen in 12 of 16 panels showing individual data (excluding S11–S14 because they were only exposed to one component length value), acquisition of discriminated responding was observed only when component lengths were 4-min long (open symbols), regardless of the order of exposure. Little discrimination was evident when the S^A component was 1 min in length (filled symbols). The single exception may have been with S08, condition 3 (4 min S^A), however the Prop of Resp in S^D was higher in the last three blocks when compared to condition 2 (1 min S^A). In every other case, though, the acquisition and repeated acquisition of an operant discrimination in a multiple schedule depended on the length of the S^A .

In the bottom eight panels (S09–S16) one can also see the unsystematic effect of component type. In some cases, for example S13 and S14, variable length components produced better discrimination (dotted lines), whereas in S15 and S16, the fixed-length components produced slightly higher DRs (solid lines). In any event, it does not appear that the component type plays a substantial role in the acquisition or repeated acquisition of an operant discrimination.

Due to the limited visual capabilities of Sprague–Dawley rats, we elected to use seemingly easily discriminable stimuli as S^D and S^A . Recall that in condition 1, the houselight and flashing houselight served as S^D and S^A , while the specific assignment was counterbalanced across subjects. In condition 2, the counterbalanced stimuli were the three stimulus lights (red, green and yellow LEDs) and those LEDs flashing, in the same manner as the houselight in condition 1. However, upon close inspection of the data, Prop Resp in S^D in condition 2 were not as high as in condition 1. The three panels on the right of Fig. 6 summarizes the results displayed in leftmost figures by averaging the data from rats exposed to identical contingencies in the three conditions, regardless of the stimuli used. Once again, these three figures clearly show the advantage of 4 min versus 1 min S^A exposure, especially in the top and bottom panels (conditions 1 and 3). The middle panel, displaying the results from condition 2, illustrates the difficulty in discriminating the LEDs from flashing LEDs. Although nearly all the rats exposed to 4 min S^A component acquired the discrimination, in contrast to the 1 min rats, overall Prop Resp in S^D were lower than condition 1. Condition 3 was conducted to repeat, and recover, the discriminated responding observed in condition 1.

Fig. 6 shows further the more rapid acquisition under an RI-30 s when compared to RI-60 s, although the difference was only statistically reliable in condition 1 (schedule $\times$ block interaction $F(4, 24) = 3.70, p = .017$, post hoc differences during blocks 3 and 4) and condition 2 (schedule main effect $F(1, 24) = 6.42, p = .04$), but not in condition 3.

Because discrimination ratios can change as a function of changes in responding in S^D or changes in responding in S^A , or both, rates of responding for individual rats are plotted in Fig. 7.

Fig. 7 shows that the clearest differentiation in responding occurred when the S^A component was 4 min in length. For example, with few exceptions, differential responding was evident when S^A components were 4 min in length, while little separation of responding in the 1 min conditions was apparent. Note also that the variable length components (back panes in gray) did not appear to influence the rate of responding or the amount of differentiation between S^D and S^A responding.

3.4. Discussion

The design of Experiment 2 sought to compare the effects of component type (fixed versus variable length), rate of reinforcement (RI-30 s versus RI-60 s), and component length (1 min versus 4 min), on the acquisition of an operant discrimination using a within-subject methodology. In addition, Experiment 2 was designed to minimize some possibly objectionable features of the first experiment.

3.4.1. Fixed versus variable component lengths—Leslie (1996) and Davison and Nevin (1999) suggest that regularly alternating components in a successive discrimination procedure allow for the possibility of a temporal discrimination to develop, or at the very least, allow for the possibility that temporal stimuli add to any extant discrimination. The present results, along with those of Andrzejewski et al. (2004), provide little support for this contention because there were no differences found in conditions with fixed or variable length components. The present experiment used a within-subjects design, whereas the fixed versus variable comparisons in Andrzejewski et al. were between-groups; together these experiments

strengthen the conclusion that fixed components have little influence on an operant discrimination. However, the results of these two studies do not rule out a possible role for fixed-length components in general, but do address the concerns one might have about fixed-length components in Experiment 1 because similar procedures with similarly trained rats were used in Experiment 2. In other words, it seems likely that under some conditions fixed-length components may affect an operant discrimination, but does not seem to play a role under the conditions of the present experiments.

3.4.2. Rate of reinforcement—Recall that in Experiment 1, higher rates of reinforcement appeared to have led to more rapid acquisition, although there appeared to be an interaction with S^A component length. In Experiment 2, the RI-30 s group did appear to acquire the discrimination more rapidly than the RI-60 s group, but only when S^A components were 4 min in length. Experiment 2, therefore, appeared to replicate the influence of rate of reinforcement. However, since there was only one comparison in the current experiment, strong conclusions about the role of reinforcement rate on the acquisition of an operant discrimination appears tenuous.

3.4.3. Component length—Component length proved once again to be a significant factor in the acquisition of an operant discrimination, regardless of the component type or rate of reinforcement. A discrimination developed only when the S^A component was 4 min in length. While this replicates the main findings of Experiment 1, the lack of discrimination in the 1 min conditions, though, contradicts the results of Experiment 1. Recall that in Experiment 1, the 1 min S^A groups acquired the discrimination, but less rapidly than the 4 min groups. In addition, it was shown that the acquisition of discrimination was invariant to cumulative time in S^A , at each schedule value. In Experiment 2, that relation was not replicated, within-subject, for no subject appeared to respond above chance in the 1 min S^A conditions, thereby obviating the companion analysis showing discrimination ratio as a function of time in S^A . In addition, the invariant relation between Prop Resp in S^D and cumulative time in S^A seemed largely a function of extinction of responding in S^A , rather than some other change in response patterns. In the present experiment, even in the 4 min S^A conditions, there was little extinction of responding in S^A . Indeed, it appeared that the increase in the Prop Resp in S^D in the 4 min S^A conditions were a result of increased responding in the S^D , rather than extinction of S^A responding, as was seen in Experiment 1 (cf. Fig. 3 with Fig. 7).

Two important, and related, differences between Experiments 1 and 2 may account for the failure to replicate. First, two different strains of rats were used, Long-Evans in Experiment 1 and Sprague–Dawley in Experiment 2. In previous unpublished studies, we have not found strain differences, although these differences may account for the differences observed in acquiring a discrimination. More importantly, recent differences in visual acuity have been reported (Prusky et al., 2002), which seem especially relevant. Second, the stimuli used in Experiment 1 were the houselight and no houselight, whereas they were the houselight/flashing houselight or LEDs/Flashing LEDs in Experiment 2. It is likely that the discrimination was more difficult in Experiment 2 when compared to Experiment 1, which may compound the effect of strain differences in visual acuity. Therefore, Experiment 3 used the stimuli in Experiment 1 to explore the invariant relation between acquisition of an operant discrimination and cumulative time in S^A , and the extinction S^A responding, within-subjects.

4. Experiment 3

4.1. Method and materials

4.1.1. Subjects—The second squad of rats used in Experiment 2 (S09–S16) served in Experiment 3. They were maintained at 80% of their free-feeding rats. Housing conditions were the same as Experiment 2.

4.1.2. Apparatus—The identical chambers used in Experiment 2 were used in Experiment 3.

4.2. Procedure

Following completion of Experiment 2, the rats were transitioned directly into Experiment 3. The first and third conditions of Experiment 3 were multiple independent RI-30 s/RI-30 s schedules, with houselight and no houselight serving as the stimuli signaling components. Both components averaged 2 min in length (variable length); component lengths were selected from two lists, without replacement, containing the values: 15 s, 40 s, 65 s, 90 s, 115 s, 125 s, 150 s, 175 s, 200 s, 225 s. Sessions started with the random presentation of one of the two stimulus conditions, after which the stimuli strictly alternated. Sessions lasted for 10 cycles, or 40 min. These conditions were run to abolish any discrimination and hopefully eliminate any bias towards responding in one stimulus configuration of the other. Sessions were run in these two conditions until responding was equal in both components ($\pm 5\%$ for three consecutive sessions). When all rats met the stability criteria, they moved directly to the discrimination portion of the experiment.

In conditions 2 and 4, rats were exposed to a mult RI-30 s/extinction schedule, with houselight and no houselight as discriminative stimuli. All components were variable in length; S^D components averaged 2 min and S^A components averaged either 1 min or 4 min. In condition 2, four rats received exposure to the 1 min S^A and four rats were exposed to the 4 min S^A . S^A length was reversed in condition 4. Thus, the design was an A–B–A–C or A–C–A–B design where A was the mult RI-30/RI-30 condition, B was the mult RI-30/Ext 1 min condition, and C was the RI-30/Ext 4 min condition. Stimulus assignment depended on the performance of each rat in conditions 1 and 3; S^D 's were assigned in opposition of any bias observed. For example, in condition 3, S09 showed a slight bias for responding in the houselight ($50\% < \text{proportion of responses in houselight} < 55\%$). Thus, the S^D in condition 4 for this rat was no houselight. In all, three rats (S09, S12 and S16) showed apparent bias for one stimulus configuration (S09 for houselight, S12 and S16 for no houselight); the remaining five rats showed no systematic bias. When the S^A component was 4 min in length, rats were run for 16 sessions; when it was 1 min they were run for 32 sessions. The first and third mult RI-30/RI-30 conditions were run for 16–19 sessions. In those conditions, all four rats in that condition were run until each rat met the stability criteria, at which time the squad of four was then transitioned into the next condition together. Each rat ran one session per day, 5–7 days per week.

As in the earlier experiments, the principal dependent measure was Prop Resp in S^D , computed by dividing rate of responding in S^D by the sum of rates in S^D and S^A .

4.3. Results

Fig. 8 shows mean Prop of Resp in S^D per blocks of five sessions for each rat in both discrimination conditions.

Fig. 8 shows that a discrimination was rapidly acquired, as a function of blocks of sessions, when the S^A components were 4 min in length, but more gradual when the S^A components were 1 min. However, in contrast to Experiment 2, under the conditions of 1 min S^A components, discriminated behavior was observed because Prop Resp in S^D were well above 0.5 for all rats. Analogous to the analysis done in Experiment 1, Prop Resp in S^D are plotted as a function of cumulative S^A time in Fig. 9.

Recall that in Experiment 1 the Prop of Resp in S^D for the 1 min group and 4 min group, as a function of cumulative S^A time, appeared to be the same (and no statistical differences were noted). The present experiment sought to replicate that finding within-subject. In two of the

rats, S09 and S10, that relation appeared to hold: the acquisition curves are nearly the same. In two other rats, S13 and S14, the terminal level of the discrimination was nearly the same, although the rapidity of the acquisition, seen in the steepness of the curve, was higher in the 4 min case. For two other rats, S11 and S12, acquisition curves appeared identical for the first three or four blocks of S^A time, but then the curves diverge from one another. For the remaining two rats, S15 and S16, the 4 min condition afforded more rapid acquisition and a higher terminal discrimination. Note that in none of the eight cases did exposure to the 1 min condition result in a consistently more rapid, or higher Prop of Resp in S^D .

S^A responding in Experiment 2 did not extinguish, even when the S^A component was 4 min in length, as opposed to Experiment 1 where nearly complete extinction was observed. Fig. 10 shows rates of responding in S^D and S^A for each rat in Experiment 3, presented in the order of exposure to the 1 min and 4 min components.

In contrast to Experiment 2, substantial reduction of S^A was found in Experiment 3, in both 1 min and 4 min conditions, although less so in the four rats exposed to the 1 min S^A in condition 4 (S11, S12, S15, and S16).

4.4. General discussion

In the present experiments, the acquisition of an operant discrimination proceeded more rapidly when the S^A components were 4 min in length, as opposed to 1 min. In addition, it may be that rate of reinforcement influences acquisition directly, with higher rates or reinforcement producing more rapid acquisitions, although the present experiments were not designed to assess the role of response rate, which are strongly influenced by reinforcement rate. The novelty of the present results lies in the fact that during discrimination training, contingencies in the presence of S^D were identical, whether between-group or within-subject. Thus, reinforcement rates in S^D were nearly identical, which suggests that both rate of reinforcement and length of extinction play important roles in acquiring a discrimination. Typically, though, the focus of discrimination training is on conditions in the positive stimulus (e.g., S^D) rather than the negative stimulus (e.g., S^A). Therefore, careful consideration must be given to both when training a discrimination. However, one limitation of the present experiments is the fact that lever-pressing was shaped first, and then a discrimination introduced. It remains an open question whether extinction would be as important if shaping and discrimination were conducted at the same time.

One unanticipated finding of the present experiments was the invariant relation between cumulative S^A exposure and proportion of responding in S^D , regardless of actual S^A length, noted in Experiment 1 (Fig. 4) and replicated in some rats in Experiment 3 (Fig. 9). In contrast to Fig. 1, which shows that a discrimination, as a function of sessions, is more rapidly acquired with longer S^A components, Fig. 4 shows that when cumulative S^A time is equated, discrimination levels are not statistically differentiated. However, by equating cumulative S^A time, the data from four consecutive sessions for the 1 min S^A groups have to be combined to arrive at one point to compare to one session of the 4 min S^A groups. Recall that during a single session, the 1 min S^A groups were exposed to 10 min of extinction. The 4 min S^A groups were exposed to 40 min; hence the need to combine four consecutive sessions ($4 \times 10 \text{ min} = 40 \text{ min}$). Because rates of reinforcement were nearly identical for the two groups within each level of reinforcement, each point for the 1 min S^A groups in Fig. 4 represent nearly four times as many reinforcers earned. The finding that these additional reinforcers have no benefit is a surprising finding.

Early accounts of discrimination learning (Skinner, 1938; Spence, 1936) suggested that discrimination was the result of progressive response strengthening in the presence of S^D and response weakening in S^A appear to receive some support here. It has been repeatedly

demonstrated that higher rates of reinforcement in interval schedules produced higher response rates. Thus, if the acquisition of an operant discrimination partly involves response strengthening in S^D , then one might expect rate of reinforcement to influence the rate of acquisition of a discrimination. An S–R associationist view of acquisition might also predict more rapid acquisition of discrimination with higher reinforcement rates, because the presumed S^D –R association underlying performance would receive more reinforcement.

Skinner and Spence's views might have also predicted that with additional response weakening in the presence of S^A , accomplished through more extinction, relative discriminated responding would increase. An associationist account would quite possibly predict a similar increase in DR because the S^A –R association, initially developed through a generalization process with S^D , would weaken because of lack of reinforcement following the S^A –R compound. However, within the context of the present results, both claims cannot be made concurrently, because neither can account for the fact that at equal total S^A exposure, discriminations are nearly the same, even though nearly four times more reinforcers have been received in the presence of S^D in the 1 min condition, although it is possible that a ceiling was reached in which additional reinforcement provided little or no additional strengthening. Experiment 1 clearly showed the relation between S^A time and DR, and although the results of Experiment 3 appeared equivocal on this matter, the 4 min conditions always produced as good, or better, discriminations than the 1 min conditions, never worse. In other words, of the two variables, cumulative reinforcers or cumulative extinction, extinction appears to be the more important aspect of training a discriminated operant. These data provide support for Keller and Schoenfeld's view that while the shaping of an operant response in the presence of a particular stimulus proceeds fairly easily, stimulus control can only be said to exist when responding extinguishes in the absence of that stimulus.

The result that longer S^A components produce more rapid acquisition of a discrimination, as a function of sessions, measured by changes in a discrimination ratio might well have been predicted, intuitively, without appeal to any learning theory. Longer extinction should produce a greater decrement in responding in that component, thus increasing the relative influence of S^D responding and increasing the discrimination. However, the function relating Prop Resp in S^D to cumulative S^A time, while similar to Sherman et al. (1964) is less intuitive. Once again, it suggests that the contribution of response strengthening in the presence of S^D to the acquisition of discriminated responding is less than the contribution of extinction in the absence of S^D .

In the end, it appears that when training any discriminated operant, consideration should be given to the events and behavior in S^A , especially if limited time and resources are at stake. In the present experiments, the primary independent variable could be seen as the ratio of S^D : S^A time (i.e., 2:1 versus 1:2), while keeping total time in S^D constant (i.e., 20 min per session), and allowing total S^A time to vary (10 min versus 40 min). It remains an experimental question, though, given a fixed amount of session time, whether a lower ratio of S^D : S^A time would result in better acquisition of discrimination.

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Fig. 1.

The four large panels show mean unbiased discrimination ratios (UDR, see Section 2.1 for description of UDR calculation) over blocks of five sessions per group for the eight groups of Experiment 1 ($\pm$ S.E.M.), differentiated by the level of reinforcement (RI-10 s, RI-30 s, RI-60 s, and RI-90 s). Closed symbols represent the groups exposed to 1 min S^{Δ} components, open symbols represent groups exposed to the 4 min S^{Δ} components. The smaller, inset graphs show acquisition curves, as function of five session blocks, for each individual rat (gray lines) in the eight groups; panels are differentiated by S^{Δ} length within each level of rate of reinforcement. The thick black line in the small panels represents the group mean. Gray rectangles, framing two points at a given block of sessions, represents a statistically reliable differences between the two groups (Tukey HSD, $p < .05$).

Fig. 2. Mean unbiased discrimination ratios for the 1 min S^{Δ} groups (top panel) and the 4 min S^{Δ} groups (bottom panel) as a function of cumulative reinforcers earned. Symbols are consistent with Fig. 1.

Fig. 3.

Mean rates of responding ($\pm$ S.E.M.) for the eight groups of Experiment 1. Mean rates of responding during all minutes of S^D exposure, differentiated by S^A length, are presented in the top four panels. Within each level of reinforcement, there were no statistical between-groups differences in mean S^D response rates. The mean rates of responding ($\pm$ S.E.M.) during the first minute of S^A exposure are presented in the bottom four panels. Gray rectangles, framing two points at a given block of sessions, represents a statistically reliable differences between the two groups (Tukey HSD, $p < .05$).

Fig. 4.

The mean Prop of Resp in S^D ($\pm$ S.E.M.) for the two S^A length groups, at each level of the rate of reinforcement factor, as a function of cumulative time in S^A . Within each level of reinforcement, no statistical differences between-groups were found.

Fig. 5.

The Prop of Resp in S^D at each level of reinforcement, regardless S^A length, as a function of cumulative S^A time in Experiment 1. At each level of reinforcement, the two series in the four panels of Fig. 4 were combined into one series and presented here.

Fig. 6.

Leftmost figures: the mean Prop of Resp in S^D ($\pm$ S.E.M.) for the 16 rats in Experiment 2, as a function of five-session blocks, for all three conditions. Closed symbols represent exposure to 1 min S^A components, while open symbols represent exposure to 4 min S^A components. Solid lines represent fixed-length components, while dotted lines represent variable-length components. Condition order is represented by symbol shape: circles/stars represent the first condition, squares/diamonds represent the second condition, and triangles represent the third condition. S01–S04 and S09–S16 were exposed to an RI-30 s schedule while S05–S08 were exposed to an RI-60 s schedule. Right figures: summary of the acquisition curves in Experiment 2, in the three conditions. The mean Prop of Resp in S^D ($\pm$ S.E.M.) are plotted as a function of blocks of five sessions, regardless of stimulus assignment.

Fig. 7.

Mean rates of responding ($\pm$ S.E.M.) in each component, across blocks of five sessions, for all three conditions, for all 16 rats in Experiment 2. Closed symbols represent response rates in S^D , while open symbols represent S^A response rate. The length of the S^A component is noted in the bottom right of each panel (1 min or 4 min). Programmed rates of reinforcement are noted at the right (RI-30 s vs. RI-60 s). Variable-length components (vs. fixed) are signified by gray back panes.

Fig. 8. Mean Prop of Resp in S^D ($\pm$ S.E.M.) as a function of five-session blocks for the eight rats in Experiment 3, regardless of order of exposure.

Fig. 9. Mean Prop of Resp in S^D ($\pm$ S.E.M.) as a function of cumulative S^A time for the eight rats in Experiment 3, differentiated by the S^A length factor.

Fig. 10.

Mean rates of responding in S^D and S^Δ components for the eight rats in Experiment 3. Series were plotted in order of the exposure to the different S^Δ lengths. Note that the x-axis is not a contiguous series because after exposure to one of the S^Δ lengths, rats were exposed to a mult RI-30 s/RI-30 s phase before exposure to the second S^Δ length.

Table 1

Condition summary of Experiment 2

Rat	Schedule	Condition 1		Condition 2		Condition 3		Summary	
		S ^d length		S ^d length		S ^d length		IV: length	
		Component type		Component type		Component type		IV: type	
S01	R1-30 s	1	F	4	F	1	F	1-4-1	n/a
S02	R1-30 s	4	F	1	F	1	F	4-1-1	n/a
S03	R1-30 s	4	F	1	F	1	F	4-1-1	n/a
S04	R1-30 s	1	F	4	F	1	F	1-4-1	n/a
S05	R1-60 s	4	F	1	F	4	F	4-1-4	n/a
S06	R1-60 s	1	F	4	F	4	F	1-4-4	n/a
S07	R1-60 s	1	F	4	F	4	F	1-4-4	n/a
S08	R1-60 s	4	F	1	F	4	F	4-1-4	n/a
S09	R1-30 s	1	F	1	V	4	V	1-1-4	F-V-V
S10	R1-30 s	1	V	1	F	4	V	1-1-4	V-F-V
S11	R1-30 s	1	V	1	F	1	V	1-1-1	V-F-V
S12	R1-30 s	1	F	1	V	1	V	1-1-1	F-V-V
S13	R1-30 s	4	V	4	F	4	V	4-4-4	V-F-V
S14	R1-30 s	4	V	4	F	4	V	4-4-4	V-F-V
S15	R1-30 s	4	F	4	V	1	V	4-4-1	F-V-V
S16	R1-30 s	4	F	4	V	1	V	4-4-1	F-V-V