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Effects of reinforcement schedules on stimulus control of discriminated operants

Efectos de los Programas de Reforzamiento sobre el Control de Estímulos en Operantes Discriminadas

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ABSTRACT

Since Ferster (1958; 1960) demonstrated that intermittent reinforcement of discriminated operants changed the stimulus control of the operants, a number of studies have been conducted on this nature of reinforcement schedules. Reinforcement schedules affect the stimulus control in several ways. For instance, when ratio schedules are adopted to reinforce units of discriminated operants, the accuracy of the operants increases: i.e., these schedules strengthen overall stimulus control of the discriminated operants. When fixed schedules, ratio or interval, are adopted, the accuracy is low soon after reinforcement: i.e., the schedules control temporal change in the strength of stimulus control of the discriminated operants. When variable interval schedules reinforce simple operants whithin units of discriminated performances, they may strengthen the stimulus control by relational aspects of the stimuli presented: i.e., the schedules may change the quality of stimulus control. This paper gives a brief review of the literature.

DESCRIPTORS: discriminated operants, stimulus control, schedules of reinforcement, conditional discrimination, matching to sample, concept formation, pigeons, rats, nonhuman primates, humans.

RESUMEN

Desde que Ferster (1958; 1960) demostró que el reforzamiento intermitente de las operantes discriminadas, modifica el control de estímulos de las operantes, se han realizado un gran número de estudios sobre esta característica de los programas de reforzamiento. Los programas de reforzamiento afectan el control de estímulo de muchas maneras, por ejemplo, cuando se emplean programas de razón para reforzar unidades de

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operantes discriminadas, se aumenta la precisión de las operantes, en otras palabras, estos programas fortalecen el control de estímulos general de las operantes discriminadas. Por otro lado, cuando se emplean programas fijos, sean estos de razón o de intervalo, disminuye la precisión inmediatamente después del reforzamiento, es decir, los programas controlan cambios temporales en la fuerza del control de estímulos de las operantes discriminadas. Los programas de intervalo variable pueden fortalecer el control de estímulos sí refuerzan operantes simples de las unidades de ejecución discriminada, esto es, pueden cambiar la cualidad del control de estímulos. Este artículo ofrece una breve revisión de la literatura sobre el tema.

DESCRIPTORES: operantes discriminadas, control de estímulos, programas de reforzamiento, discriminación condicional, igualación de la muestra, formación de conceptos, pichones, ratas, primates no humanos, humanos.

Schedule of reinforcement is one of the most important variables that determines the quantity and quality of operant performances. As Ferster (1958; 1960) demonstrated, it controls not only simple operants but also complex chains of discriminated responses in a similar fashion: that is, when the complex units of the discriminated responses were intermittently reinforced, the cumulative records of the emission of the units were typical of simple operants under the same schedule. Interestingly, he found that the accuracy of the discriminated responses was controlled by the reinforcement schedules as well. This means that stimulus control of discriminated operants may change when the operants are reinforced with different schedules. Much of the behaviors of humans and higher animals are complex operants which are intermittently reinforced with certain schedules. In some cases the simple operant responses which construct the complex chain are also intermittently reinforced by a certain stimulus change that advances the chain. The systematic study of the effects of intermittent reinforcement on stimulus control of discriminated operants is therefore of considerable importance for the understanding of complex behavior of higher animals.

A substantial amount of such study has been conducted after Ferster. Most of the studies employed a conditional discrimination task, matching to sample, as a unit of discriminated operant. More simple discrimination performances such as brightness discrimination and time discrimination have also been studied. In most studies, the subjects employed were pigeons. The number of studies that examined performances of other animal species is unfortunately small. However, no considerable difference across species and tasks in the effects of reinforcement schedules on stimulus control of discriminated responses was so far reported. In the present paper, I will make a brief review of the literature and point out some problems remained unsolved on this issue.

Intermittent reinforcement of complex units of discriminated operants

Fixed-ratio performances. The improvement of overall accuracy of discrimination performances under fixed-ratio (FR) schedule was first reported by Ferster (1958). A chimpanzee was trained to press a second lever after pressing a first three times. He reinforced this fixed-consecutive-number responses with FR schedules ranging FR 1 to FR 33. Accuracy of responses increased as ratios increased. Ferster (1960) replicated his finding with another species, pigeons, and a more complex conditional discrimination task, matching to sample. This time he tested ratios ranging 1 to 95. He found that the matching accuracy was near chance under FR 1 (continuous reinforcement: CRF) and increased as ratios increased up to around 15 to 20. Bigelow (1971) showed similar increase in accuracy as a function of FR value (3 to 20) in a more simple task, DRL (differential reinforcement of low rates of responding) performances in rats. Similarly, Rohles (1961) reported increase in accuracy of oddity discrimination by a chimpanzee under FR schedules of the size up to 19.

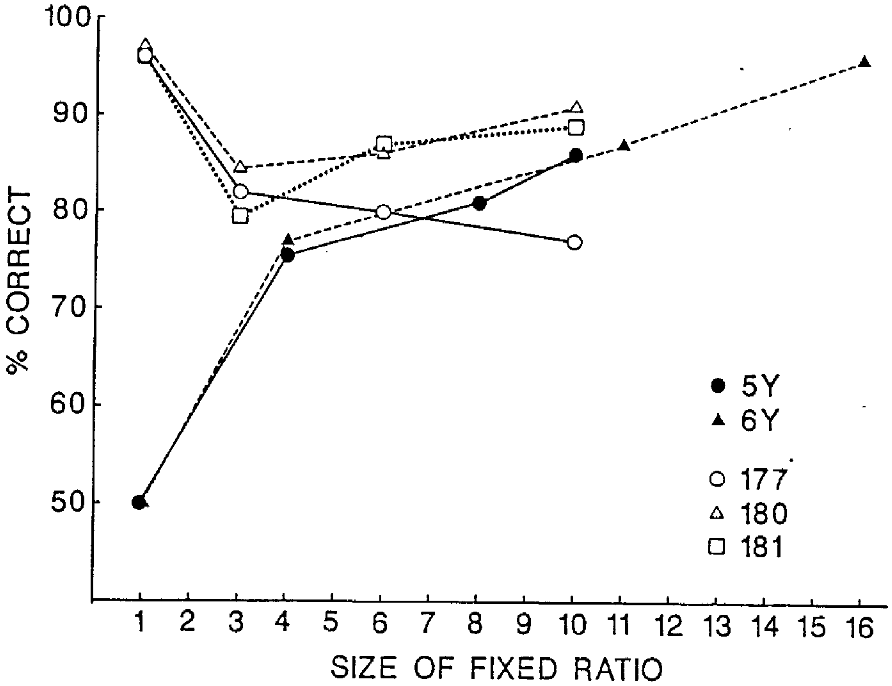

Figure 1. The relationships between the accuracy of matching-to-sample discrimination by pigeons and the size of the fixed ratio which reinforces correct matching responses. The matching accuracy of pigeons of Ferster (1960) (5Y and 6Y) increased as the size of the ratio. In contrast, pigeons used by Nevin, et al. (1963) (177, 180, and 181) showed the highest matching accuracy under FR 1 (continuous reinforcement). The difference in the overall accuracy between the two studies seems to be because Ferster (1960) used a 0-delay matching-to-sample procedure while Nevin, et al. (1963) employed a simultaneous matching-to-sample procedure. The data are redrawn from Ferster (1960) and from Nevin, et al. (1963).

On the other hand, Nevin, Cumming, and Berryman (1963) reported the opposite effect of FR schedules. They found pigeons' matching-to-sample accuracy the highest under CRF. Figure 1 shows the contrasting results of Ferster (1960) and Nevin, et al. (1963). The procedure employed by Nevin, et al. (1963) have a number of differences from that employed by Ferster (1960), two of which seem to be important. First, Ferster conditionally reinforced correct matches that did not satisfy FR requirement with a brief flash of a food hopper and punished all incorrect responses with a timeout, while Nevin, et al. (1963) employed no inmediate differential consequences of correct and incorrect responses that did not satisfy the ratio. The presence of the differential contingencies of conditioned reinforcement seem to be important to keep good accuracy of discrimination. In fact, Stubbs and Galloway (1970) demonstrated that, under schedules of low rates of reinforcement, accuracy of conditional position discrimination by pigeons increased when a conditioned reinforcer was present after unreinforced correct responses. In addition, the absence of timeout punishment of incorrect responses that did not reach the ratio may have lowered the accuracy. Ferster and Appel (1961) demonstrated the function of timeout of moderate length (up to around 60 sec) to increase the accuracy of pigeons' matching-to-sample performances. When Zimmerman and Ferster (1963) intermittently punished pigeons' matching errors, the accuracy decreased as the frequency of the timeout punishment decreased. Zimmerman and Baydan (1963) obtained the same results with conditional matching-to-sample performances by humans.

Second, Fester (1960) used no intertrial intervals (ITI), while Nevin, et al. (1963) used ITI of 25 sec during initial acquisition of matching. Holt and Shafer (1973) studied the effects of ITIs of various lengths (0 to 60 sec) on matching-to-sample behavior of pigeons. They found that the pigeons failed not only to acquiere a matching performance but also to maintain it without an ITI. This was because the pigeons randomly responded on the sample and the comparison keys without observing them, and the random responses supplied high rates of reinforcement. On the other hand, acquisition of the performance was the fastest with ITIs longer than 25 sec. Nelson and Wasserman (1978) also found that the accuracy of delayed successive matching to sample by pigeons was an increasing function of the duration of ITI (5-50 sec). Thomas (1979) obtained similar results in testing an interaction between length of ITI and FR size in matching-to-sample performance by pigeons. He found that accuracy under CRF was considerably low without an ITI but was as high as those under FRs up to 40 with ITIs of larger than 5 sec. The presence or absence of ITI of some length is thus a critical variable that determines CRF performances. But the interaction between the effects of ITI and the function of FR schedules of various sizes on the accuracy of discrimination is not very clear yet. In the first determination, Thomas (1979) obtained an increase of matching accuracy as the size of the ratio was up to around 20 or 40, just as Ferster (1960) did. This contrasted with a fairly constant accuracy under FRs ranging 1 to 20 with and ITI. In the second examination of no-ITI performances, however, both of his pigeons showed constant accuracy under FRs ranging 5 to 20.[1] Similarly, in testing matching-to-sample peformances by human children without an ITI, Davidson and Osborne (1974) obtained constant matching accuracy under ratios 3 to 10.

Fujita (1985) suggested that difference in the stage of learning was critical for the effect of FR schedules. Japanese monkeys were concurrently trained on three similar conditional position discrimination task with CRF, FR 5, and VR 5 (variable-ratio 5) schedules with and ITI of .5 sec. At the beginning of learning, accuracy increased most rapidly when the discriminated responses were reinforced with CRF. But once the accuracy reached a moderate level (around 70 to 80%), two ratio schedules, fixed or variable, were more effective in maintaining the accuracy high. As the discrimination approached an asymptote, accuracy was less susceptible to the effects of reinforcement schedules. When rations were increased thereafter, the monkeys kept the same level of accuracy under FRs up to 20. Nevin (1967) found similar independence of accuracy from the rate of reinforcement after establishig the simultaneous discrimination of brightness by pigeons. This interaction between effects of ratio schedules and learning stage may explain, at least in some part, inconsistent data of previous researchers. One may obtain an increasing function between FR size and accuracy like Ferster (1960) and the first examination of Thomas (1979) only during early portions of the maintenance stage of the experiment.

FR schedules of large sizes strain the performance. For example, Fujita (1985) obtained a ratio of 20 as a maximum size of the ratio to sustain accurate conditional discrimination by monkeys (Figure 2). Both the accuracy (unfilled symbols) and the rates of trials (filled symbols) dropped heavily under ratio 30, showing a strained performance at this ratio. Interestingly, the maximum ratios of similar sizes (around 20 or 30) were obtained in two other studies in which matching-to-sample peformances by pigeons were examined (Ferster, 1960; Thomas, 1979). It is possible that the total number of simple operants to obtain food limits the size of the ratio that may sustain the peformance. But it is likely that the critical ratio changes according to many other independent variables such as species of the subject, amounts and types of reinforcement, levels of deprivation, difficulty of the task, etc. It should be noted that the ratios described above are no more than examples.

In summary, the effects of FR schedules on the overall accuracy of discrimination changes with presence or absence of ITI and the difference in the learning stage. Without an ITI, FR reinforcement of moderate size (up to around 20) is necessary both for the establishment and maintenance of discriminated performances. With an ITI, FR schedules are efficient only during periods when the stimulus control of the discrimination was at a moderate level. When conditioned reinforcement of unreinforced correct responses is omitted, FR performances may be worse.

FR schedules control temporal patterning of correct and error runs. All

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[1] It should be noted that the first determination of no-ITI performance was conducted under a correction procedure, while the second under a non-correction procedure. This might have affected performances under FRs.

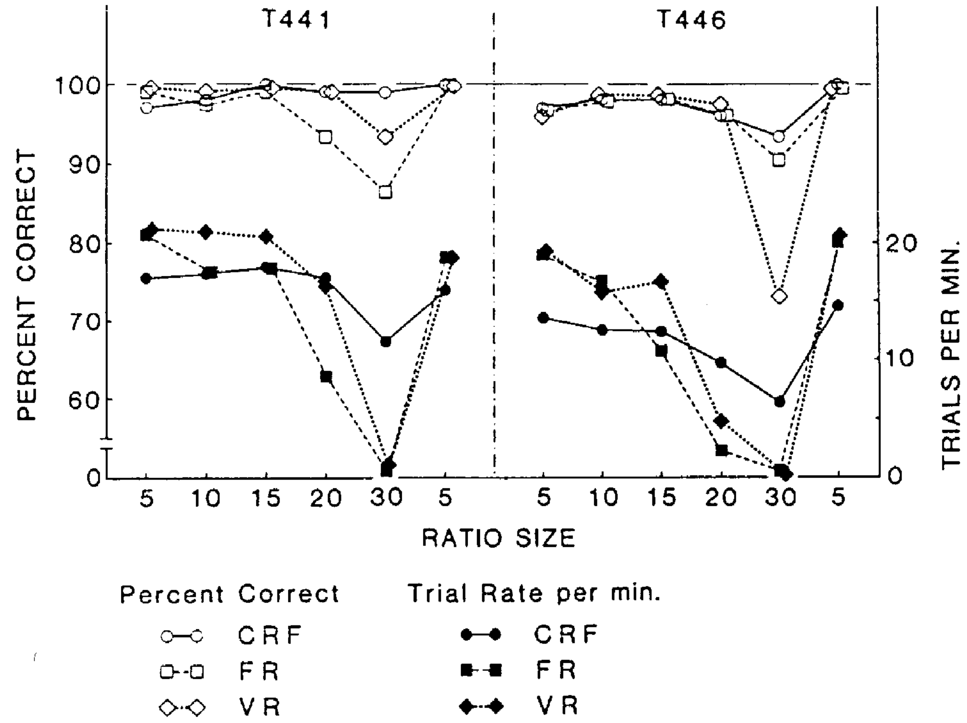

Figure 2. The relationships between the size of the ratio in FR and VR schedules and the rates of responses (trial rate: filled symbols) and the accuracy (unfilled symbols) of conditional position discrimination by Japanese monkeys obtained in Fujita (1985). Both the trial rates and the accuracy substantially decreased at ratio 30, showing strained performances.

pevious studies that employed FR reinforcement of matching-to-sample performances reported that errors were frequent in the early part of the ratio run and decreased as the number of correct responses approached the ratio requirement (with pigeons: Nevin, et al., 1963; Mintz, Mourer, & Weinberg, 1966; Holmes, 1979; Boren & Gollub, 1972; Thomas, 1979; with human children: Davidson & Osborne, 1974). The same phenomenon was replicated when different discrimination tasks were employed and different species were tested. For example, as is shown in the upper graphs of Figure 3, Fujita (1985) obtained a clear increase of the accuracy as a function of cumulative number of correct responses in conditional position discrimination based on color by Japanese monkeys. This was remarkable in the performances under larger ratios. Similar results were obtained in discrimination of brightness by pigeons (Nevin, 1967) and in discrimination of stimulus duration by pigeons (Stubbs, 1968). Therefore the effect of FR schedules on temporal change in the streght of stimulus control is consistent independently of the kinds of discrimination task or species.

Variable-ratio performance. The effect of VR schedules on overall accuracy of discriminated responses is somewhat unclear. For example, Nevin et

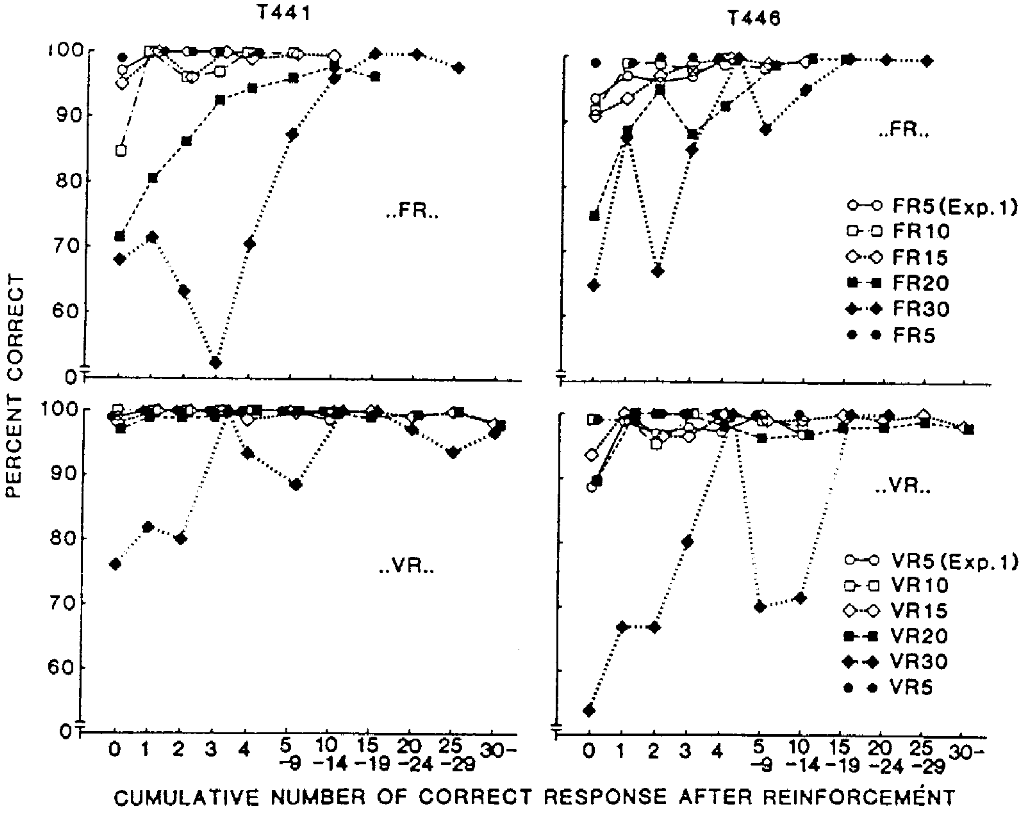

Figure 3. The relationships between the accuracy of conditional discrimination performances by Japanese monkeys and the cumulative number of correct responses after reinforcements under ratio schedules of various sizes. The data are those obtained in Fujita (1985). When the discriminated responses were reinforced with FR schedules, the accuracies were low during the early portions of the ratio run (upper two graphs). This was remarkable under large FRs (FR 20 and 30). On the contrary, when the responses were reinforced with VR schedules of the size up to 20, the accuracies were largely constant without regard to the number of correct trials after reinforcement. However, the subjects showed decreases in the accuracy during the early part of the ratio run under a large VR schedule (VR 30), just as those under FR schedules.

al. (1963) found that under a VR 3 schedule matching-to-sample accuracy by pigeons was not very different from that under CRF, and it was higher than that under FR schedules (ratios 3 to 10). Stubbs (1968) observed that discrimination of stimulus duration by pigeons was more accurate under VR 10 than under FR 6 with FR counter reset by errors (though, of course, this may have been due to the difference in the overall ratio). Davidson and Osborne (1974), who tested matching-to-sample behavior of human children, found that the accuracy was much the same between FR and VR scheedules. As described earlier, Fujita (1985) found no systematic differences in overall accuracy of conditional discrimination by Japanese monkeys between FR and VR schedules during both acquisition and maintenance stages. The two schedules improved accuracy of the discrimination only during the early periods of maintenance stages of learning. So far, no experimental reports suggested inferiority of VR schedules to FR. It is likely that VR schedules and FR schedules have similar effects on overall accuracy of discrimination during both acquisition and maintenance stages. However, the effect of VR schedules of different sizes has not been studied systematically yet.

The relationship between accuracy and VR count was consistent among most of the previous studies without regard to the species or tasks employed: the accuracy does not change according to VR count (Nevin, et al., 1963; Nevin, 1967; Stubbs, 1968; Davidson & Osborne, 1974). Only one exception was Fujita (1985). In this study, performances of Japanese monkeys with VR ratios up to 20 were consistent with the previous studies. But when the ratio increased to 30, the accuracies were low in the early portions of the ratio run (see lower graphs of Figure 3). Therefore, large VRs may produce the same temporal pattern of correct and incorrect responses as FR schedules do.

Fixed-interval and variable-interval performances. Ferster (1960) compared the accuracy of pigeons' matching-to-sample performances under FI (length: 5 min and 10 min) and under VI (length: 6 min and 9 min) with those under FR schedules (range: 10 to 25). Rates of errors increased under both interval schedules. Under interval schedules, fixed or variable, overall rates of reinforcement do not differ much whether the subject performs with 100% accuracy or with the accuracy of a chance level. This may explain the inefficiency of both interval schedules for maintaining accurate performances. Of course, Ferster's finding may have been a consequence of extremely low rates of reinforcement under the interval schedules employed. In fact, human children tested by Davidson and Osborne (1974) performed matching to sample under much shorter FI (range: 12-40 sec) and VI (24 and 40 sec) with accuracies similar to those under FR or VR (range: 3-8) schedules. Similarly, when Japanese monkeys were extensively trained on matching to sample with VI 60 sec, the performances were about 90% correct (Kojima, 1982). It is possible that, as Fujita (1985) demonstrated in FR and VR schedules, once the peformance reached an asymptote, the discrimination do not deteriorate under interval schedules of moderate lengths.

Several studies examined the relationship between the local accuracy of discrimination and the time after the reinforcement under FI schedules. Ferster (1960) and Boren and Gollub (1972) reported that matching-to-sample errors by pigeons most frequently occurred in the second quarter of the interval and the accuracy increased near the end of the interval. Figure 4 shows the relationship between matching accuracy and time after reinforcement under FI schedules obtained by Ferster (1960). Nelson (1978) got similar results in his first determination, though three out of four pigeons made more errors in the first quarter in the second determination. Clark and Sherman (1970) reported that pigeons' matching accuracy was the lowest in the first quarter and increased near the end of the interval. With human chil-

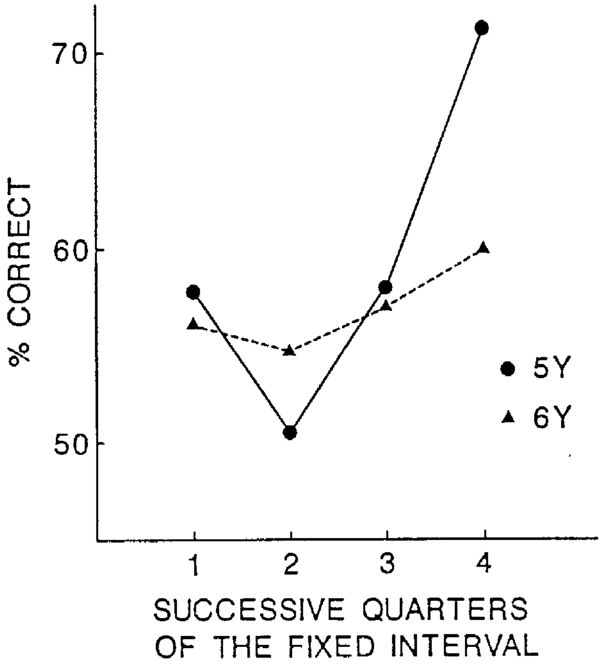

Figure 4. The change of the accuracy of 0-delay matching-to-sample discrimination by pigeons under FI 10-min schedules as a function of time after reinforcement. The data are redrawn from Figure 16 of Ferster (1960). The accuracy of discrimination was low during early periods after reinforcement and increased as time passed and approached the interval value.

dren, Davidson and Osborne (1974) found that they made the highest number of errors in the second quarter. Although there is an inconsistency in the exact part during which errors are most frequent, FI schedules seem to control correct discrimination in a scallop pattern. Probably this is because correct responses soon after the reinforcement are never reinforced. On the other hand, Davidson and Osborne (1974) found that, under VI schedules, frequency of errors did not change as a function of time passed from the previous reinforcement. This seems to be because local probability of reinforcement do not differ under VI schedules.

Intermittent reinforcement of simple operants within units of discriminated operants

So far, only a few studies have attempted to examine the effects of intermittent reinforcement adopted within units of discriminated operants. Sacks, Kamil, and Mack (1972) tested pigeons' matching-to-sample discrimination with the fixed ratio requirement on the responses to the sample to produce comparison stimuli, with ratios changed between 1 and 40. They found that the larger the ratio the faster the pigeons acquired the discrimination and the better the accuracy when the delay of several lenghts was inserted between offset of the sample and onset of comparison stimuli (i. e., a delayed matching-to-sample task). Similar facilitation of more simple discrimination learning was obtained by Williams (1971). He trained pigeons on a color alternation task with FR values within a trial varied between 1 and 30. Only pigeons trained with ratios larger than 15 acquired accurate performance. These two studies suggest than FR schedules adopted within units of discrimination trial increase the strength of stimulus control.

However, the fact is not so simple. Lydersen, Perkins, and Chairez (1977) examined oddity-from-sample[2] performances of pigeons with fixed-ratio requeriments to both sample and comparison stimuli changed between 1 and 32. As is shown in Figure 5, they found that the accuracy of the discrimination was, as the previous two studies found, an increasing function of the size of the ratio on the sample (upper graph), but was a decreasing function of the size of the ratio on the comparison stimuli (lower graph). The FR requirements arranged on the sample may strengthen the instructional function of the sample (Cumming & Berryman, 1965) by increasing the duration of and the attention to the sample. But, in the absence of the sample (0-delay procedure was used in Lydersen et al. (1977)), the FR requirements arranged on comparison stimuli have no such function. Probably the negative effect on the accuracy of discrimination of FR arranged on comparison stimuli is a consequence of the delay of reinforcement (Cox & D'Amato, 1977). It seems that FR schedules strengthen stimulus control only when they are adopted on the stimulus that instructs the following response. This effect may be, at least partly, due to lengthened duration of sample presentation. Nelson and Wasserman (1978) found that the accuracy of delayed successive matching to sample by pigeons increased as sample duration lengthened from 1 sec. up to 12 sec.

Intermittent reinforcement sometimes changes the quality of the stimulus control of the discriminated behavior. It was reported that VI schedules adopted within the unit of same/different discrimination task enhanced the stimulus control by the relational aspects among stimuli (Fujita, 1983, see Carter & Werner, 1978 for other possible sources of stimulus control) Japanese monkeys were trained to press a lever only in the presence of identical stimulus pairs. The responses were reinforced according to a VI schedule. Three out of four monkeys showed clear transfer of this discrimination trained with two colors to two new colors (Figure 6). The effect of VI schedules to enhance relational stimulus control was replicated by Fujita with reinforcement choice responses in simultaneous matching to sample task with reinforcement of choice responses in simultaneous matching to sample task with a VI schedule. Honig (1965), Malott and Malott (1970), Malott, Malott,

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[2] A task in which the choice response on the comparison stimuli that *do not* match the sample is reinforced. It is sometimes called "nonmatching to sample".

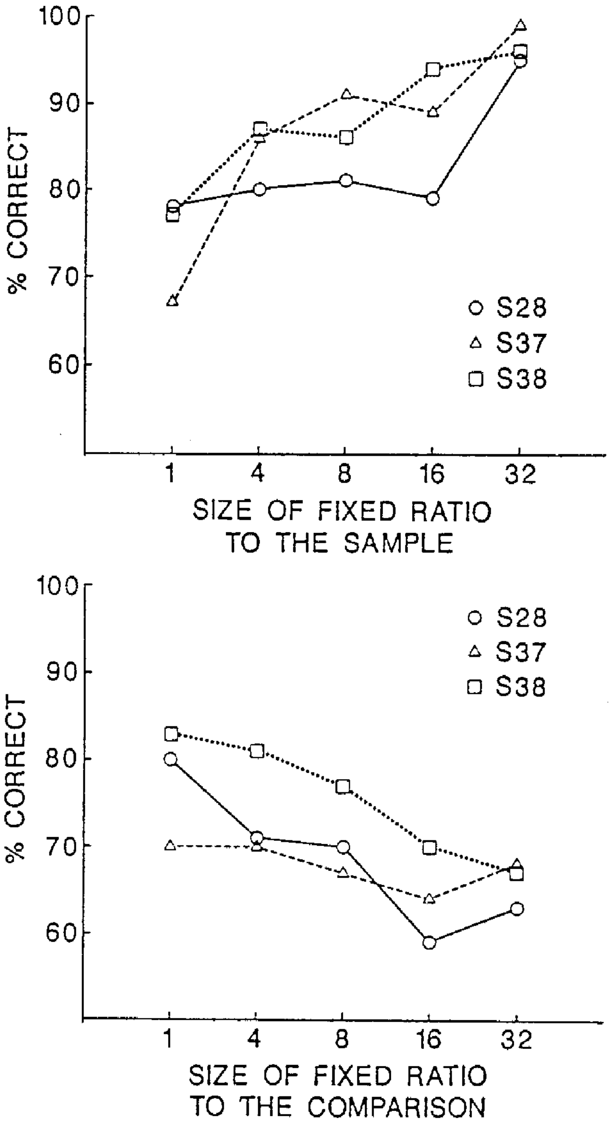

Figure 5. The accuracy of 0-delay matching-to-sample peformances by pigeons when the number of responses on the sample required to produce the comparison stimuli were varied while the number of responses on the comparison stimuli were kept to 1 (upper graph) and that when the number of responses on the comparison stimuli were varied while the requeriment on the sample was kept to 1 (lower graph). The accuracy increased as a function of the size of the FR on the sample while it decreased as a function of that on the comparison stimuli. The data are redrawn from Figure 2 of Lydersen, eta al. (1977).

Svinicki, Kladder, and Ponicki (1971) obtained similar successful transfer of same/different discrimination by pigeons reinforced with VI schedules adopted within trials. I suggest the function of VI schedules to enhance stimulus

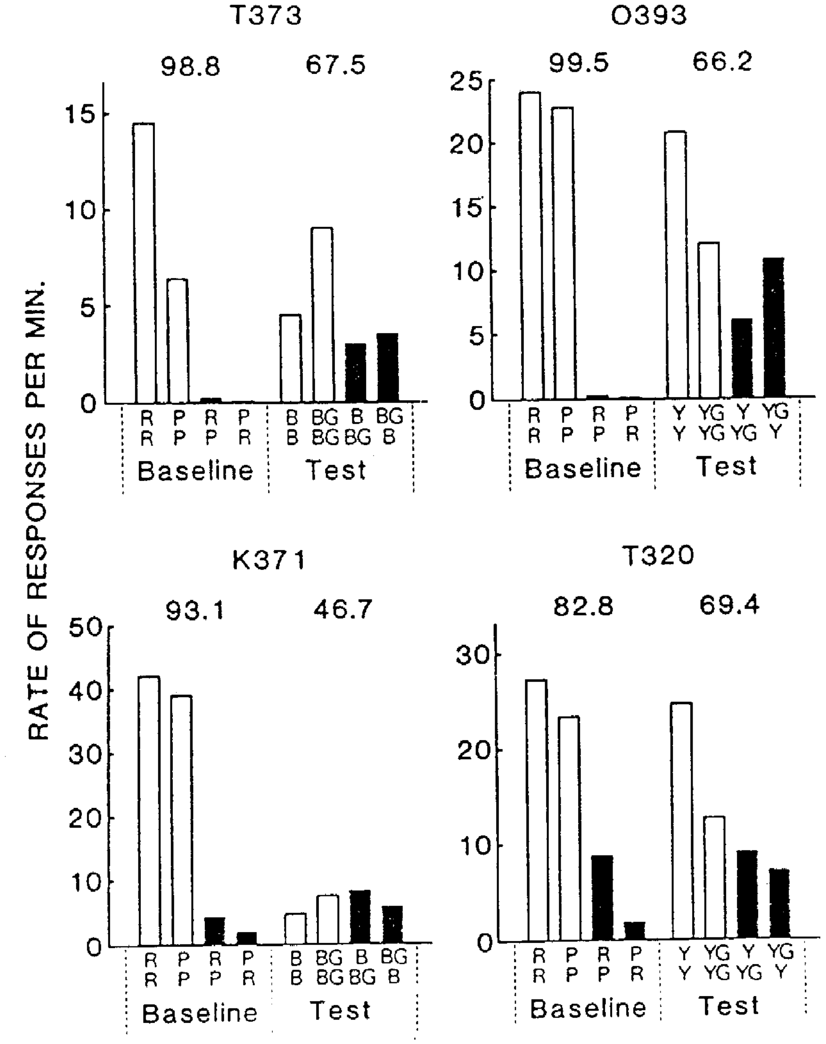

Figure 6. The results of the transfer test of a succesive go/no-go discrimination of 'same' pairs and 'different' pairs by Japanese monkeys obtained in Fujita (1983). In the baseline condition, only responses in the presence of matched colors (red and purple) were reinforced according to a VI 20 sec schedule. In the transfer test, in which two new colors (blue and bluegreen or yellow and yellowgreen) were presented, all responses were extinguished. White bars represent response rates in the presence of matched colors and black bars designate those under mismatched colors. The numerical values above the graphs show discrimination indexes calculated as percentage of the response rates under matched colors to the sum of that under matched colors and that under mismatched colors. Three of the four animals showed successful transfer of this discrimination.

control by external stimuli compared with VR schedules (Thomas & Switalski, 1966) or DRL (Hearst, Koresko, & Poppen, 1964) is an important factor which provides strengthened relational control (for a detailed discussion, see Fujita, 1983; Rilling, 1977).

In order to examine this hypothesis, I tested the transfer of the same/different discrimination which had VR schedules within trials (Fujita, unpublished data). Two monkeys were first trained to press a lever only when the two colors on the stimulus display matched. Three colors, red, purple, and blue, were used during training. After acquisition of this one-response go/no-go discrimination, the monkeys were tested for transfer of the same/different discrimination to three new colors, yellow, yellowgreen, and bluegreen, without reinforcement. Thereafter, the number of responses necessary to produce food reinforcement was gradually increased up to VR 20 for one subject and VR 30 for the other. The transfer of this multiple-response go/no-go discrimination to the three colors was then tested. As in the first transfer test, transfer responses were never reinforced. Finally they returned to one-response procedure and received a final transfer test with the three colors. Figure 7 shows the accuracy of this same/different discrimination in

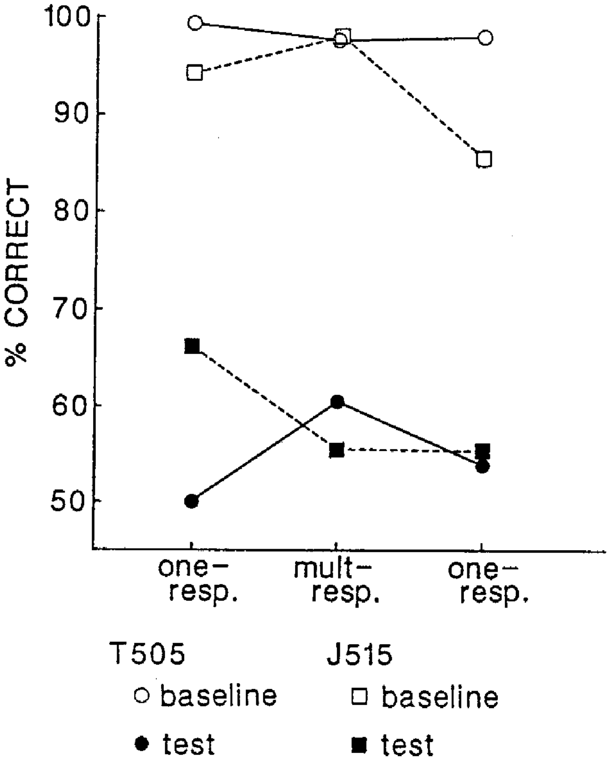

Figure 7. The results of transfer tests of a successive go/no-go discrimination of 'same' pairs and 'different' pairs by Japanese monkeys. In the baseline training, only responses in the presence of matched colors (red, purple, and blue) were reinforced with CRF (one-response condition) or VR schedules of the size 20 or 30 (multiple-response condition). In the trials of transfer test, in which three new colors (blue, bluegreen, and yellowgreen) were presented, all responses were extinguished. In contrast with the successful transfer of similar go/no-go discrimination with a VI reinforcement trained with only two colors (Figure 6), the accuracies in transfer trials were little more than chance in all three tests. See text for details.

three transfer tests. One monkey showed somewhat successful transfer in the first transfer test. But for all other phases, transfer preformances of either monkey were little more than chance. This contrasted with the successful transfer shown by the monkeys in Fujita (1983), obtained after go/no-go discrimination of "same" and "different" with only two colors, in which responses in the presence of two matched colors were reinforced with a VI 20-sec schedule.

VI and VR schedules have many aspects in common. For instance, the duration of stimulus presentation is increased, there is an increase in the number of unreinforced responses made in the presence of positive stimuli, a lower rate of reinforcement, and an irregular presentation of reinforcement. If any of these factors were responsible for successful transfer of the same/different discrimination, transfer should have occurred when VR schedules were arranged within the discrimination trial. A critical difference between VI and VR schedules is that on VI schedules the rate of reinforcement is scarcely affected by the rate and temporal patterns of responding. As Rilling (1977) suggested, this may lead to stronger stimulus control by external stimuli in VI schedules. The nature of VI schedules to strengthen external control seem to be the factor that enhaced the relational stimulus control.

Summary and conclusions

I briefly reviewed the effects of four reinforcement schedules on the stimulus control of discrimination performances. They change three aspects of stimulus control: overall strength of it, temporal pattern in its strength, and quality of it. Particular schedules have particular functions. The following summarizes these effects.

When the schedules are adopted across discrimination trials.

1. Ratio schedules of moderate size increase overall strength of stimulus control during periods when the accuracy of the discrimination is at a moderate level.
2. Interval schedules may decrease overall strength of stimulus control. But when the discrimination is well established, the performance may be maintained under interval schedules of moderate lengths.
3. Under fixed schedules, ratio or interval, the strength of stimulus control is weak soon after reinforcement and is stronger as the availability of reinforcement increases to the final requirement.
4. Under variable schedules, ratio or interval, the strength of stimulus control is always constant. Under large VRs, however, errors may be frequent soon after reinforcement.

When the schedules are adopted within discrimination trials,

1. When fixed-ratio schedules are adopted on the stimulus which instructs the following choice response, they increase overall strength of stimulus control.
2. When responses in the presence of a set of discriminative stimuli are rein-

forced with variable interval schedules, the schedules may enhance stimulus control by the relational aspects of the stimuli.

It should be noted that not all of these points have been demonstrated in a variety of species and tasks. Althoung it is accepted that the effects of reinforcement schedules are in general replicable across species and types of operants (e.g., Zeiler, 1977), their effect on stimulus control should be examined with a variety of species and tasks.

At the same time, it is necessary to determine which aspect of particular schedules is critical to exhibit particular functions. For example, intermittent reinforcement gives lower rates of reinforcement than CRF schedules. Previous results suggest that the rate of reinforcement in itself is not sufficient to explain variable effects of reinforcement schedules, since ratio schedules adopted across discrimination trials strenghten stimulus control whereas interval schedules do not. But the rate of reinforcement is a parameter which can be operated independently from reinforcement schedules. Yoked-control experiments provides a situation that separates the effect of schedules and the rate of reinforcement.

The dependency of the rate of reinforcement upon accuracy of the discrimination is another independent variable. In usual interval schedules, the rate of reinforcement changes little with accuracy. What happens when, say, 90% accuracy is needed during interreinforcement periods to obtain a reinforcer in interval schedules? What happens if the first correct response after *n* trials is reinforced without regard to the number of correct responses during inter-reinforcement periods in ratio schedules? Such studies would identify the effect of the dependency of the rates of reinforcement upon accuracy.

Finally, the effect of reinforcement schedules on the quality of stimulus control suggested by Fujita (1983) is another interesting aspect to study. Every stimulus has a multidimensional nature: for example, a visual stimulus has its hue, brightness, contrast, shape, duration, etc. as its features. When two or more stimuli are presented, relational aspects among the stimuli are added. All of the features included in the stimulus can function as a discriminative stimulus to control the organism's behavior. When one attemps to establish discriminated operants controlled by the desired feature of the stimulus, one should take reinforcement schedules into account. The study of reinforcement schedules on the quality of stimulus control is thus an important topic to establish the best procedures for the analysis of a variety of aspects of behavior.

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