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SOFT COMMITMENT: SELF-CONTROL ACHIEVED BY RESPONSE PERSISTENCE

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With reinforcement contingent on a single peck on either of two available keys (concurrent continuous reinforcement schedules) 4 pigeons, at 80% of free-feeding weights, preferred a smaller-sooner reinforcer (2.5 s of mixed grain preceded by a 0.5-s delay) to a larger-later reinforcer (4.5 s of mixed grain preceded by a 3.5-s delay). However, when the smaller-sooner and larger-later reinforcers were contingent on a concurrent fixed-ratio 31 schedule (the first 30 pecks distributed in any way on the two keys), all pigeons obtained the larger-later reinforcer much more often than they did when only a single peck was required. This "self-control" was achieved by beginning to peck the key leading to the larger-later reinforcer and persisting on that key until reinforcement occurred. We call this persistence "soft commitment" to distinguish it from strict commitment, in which self-control is achieved by preventing changeovers. Soft commitment also effectively achieved self-control when a brief (1-s) signal was inserted between the 30th and 31st response of the ratio and with concurrent fixed-interval 30-s schedules (rather than ratio schedules) of reinforcement. In a second experiment with the same subjects, the fixed ratio was interrupted by darkening both keys and lighting a third (center) key on which pecking was required for various fractions of the fixed-ratio count. The interruption significantly reduced self-control. When interruption was complete (30 responses on the center key followed by a single choice response), pigeons chose the smaller-sooner reinforcer as frequently as they did when only a single choice response was required.

Key words: commitment, pattern, self-control, choice, key peck, pigeons

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Self-control has been defined as choice of a larger-later (LL) reinforcer over a smaller-sooner (SS) reinforcer; *impulsiveness* is the reverse choice (Ainslie, 1974; Logue, 1988; Rachlin & Green, 1972). For instance, Rachlin and Green found, with alternatives of 2 s of food available immediately (SS reinforcer) and 4 s of food available after a 4-s delay (LL reinforcer), that pigeons strongly preferred the SS reinforcer: the pigeons were thus impulsive. However, impulsiveness can be overcome and self-control can be achieved by means of strict commitment. The effectiveness of commitment depends on choice reversal. At an earlier point, when both smaller and larger reinforcers are delayed by a relatively long period of time, the LL reinforcer may be preferred. But as time passes, preferences may reverse and the SS reinforcer may come to be chosen. The consequence of this subsequent preference reversal may be prevented by commitment at the earlier point to the LL reinforcer. In previous studies the commitment response, at a time when the LL reinforcer was preferred, made the SS reinforcer absolutely unavailable.

Figure 1 illustrates the design of typical studies of commitment with pigeon subjects (e.g., Rachlin & Green, 1972) and human subjects (e.g., Solnick, Kannenberg, Eckerman, & Waller, 1980). Subjects, offered Choice X at t_2, preferred an SS reinforcer to an LL reinforcer. However, at an earlier point, t_1, subjects offered Choice Y preferred the lower branch, a take-it-or-leave-it choice of LL, to the upper branch, leading to Choice X. In other words, pigeon and human subjects chose at t_1 to restrict their choice at t_2; they committed themselves to LL. Preference for commitment in these studies varied directly with the interval, $t_2 - t_1$. As this interval increased, subjects came more and more to choose the commitment alternative. If self-control is defined as obtaining LL, commitment may be seen as a method of achieving self-control (Ainslie, 1974; Logue, 1988; Rachlin, 1994).

The reversal of preference between the point in time of Choice X, at which SS is preferred, and that of Choice Y, at which LL is preferred, is predicted by nonexponential temporal discount functions such as Mazur's (1987) hyperbolic function,

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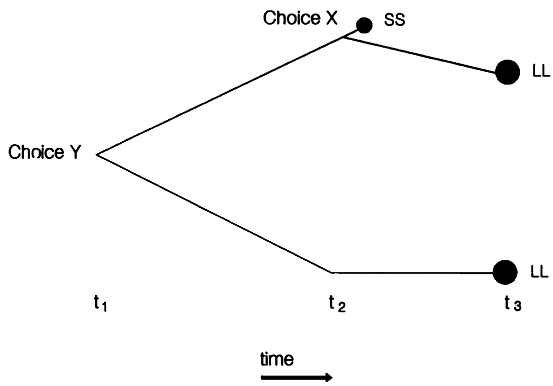

Fig. 1. Alternatives in an experiment by Rachlin and Green (1972) on commitment in pigeons. Pigeons choosing (Choice X at time t_2) between a smaller-sooner (SS) reinforcer and a larger-later (LL) reinforcer strongly preferred the SS reinforcer. However, at a prior point in time (Choice Y at t_1), pigeons preferred an alternative (the lower branch) that restricted their choice to LL only.

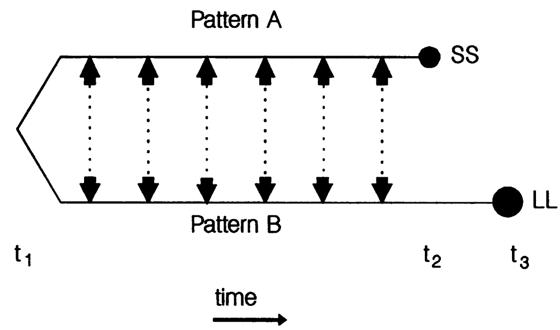

Fig. 2. Design of the present experiments. Concurrent schedules of reinforcement required a pattern of responses leading to either SS or LL. Subjects were free to move between the two patterns. Preference is predicted by Equation 1 (temporal discount function) to change from LL at t_1 to SS at t_2.

$$v = V/(1 + kD), \quad (1)$$

where V is the undiscounted value of the reinforcer, v is the discounted value of the reinforcer, D is delay of the reinforcer from the present moment, and k is a constant proportional to degree of discounting.

Differences between individuals in k imply differences in self-control. Higher k means greater delay discounting and therefore less self-control. In direct tests of Equation 1, values of k for pigeons have been several orders of magnitude higher than those for human subjects (Mazur, 1987; Rachlin & Raineri, 1992). For human subjects, k is higher for children than for young adults, and higher for young adults than for elderly people (Green, Fry, & Myerson, 1994).

Despite the analogous behavior of pigeons and people in the commitment paradigm illustrated in Figure 1, commitment is rarely so rigid in everyday life. For instance, people most often alter their eating patterns without committing themselves to an institution where food is strictly rationed or without wiring their jaws shut. We call their commitment in these cases *soft commitment.* People frequently commit themselves to a healthy pattern of eating, yet nevertheless "change their minds" at some point and defect from their planned diets. If diets were always abandoned, it would be possible to dismiss such soft commitment as no commitment at all. But diets are at least sometimes not abandoned. Occasionally the second dessert is refused; the alcoholic drink, the cigarette, the drug, the adulterous invitation, and so forth, are refused, even though they could be accepted. In the laboratory, some children will sometimes wait several minutes for larger rewards even when smaller rewards are immediately available (Mischel, Shoda, & Rodriguez, 1989).

The standard explanation for soft commitment (e.g., Ainslie, 1992; Schelling, 1992) is that it is an internalized form of hard commitment; the person who refuses the second dessert is said to be bound by an internal constraint if not an external one. This sort of internalization replaces the behavioral model of Figure 1 with a cognitive or physiological model.

Without denying or endorsing any particular cognitive or physiological underlying mechanism, the present series of experiments investigated the coherence of behavioral patterns per se. Our model views temporally extended patterns of overt behavior as coherent units in themselves (Mowrer, 1960; Nevin, Mandell, & Atak, 1983; Rachlin, 1994; Skinner, 1953). Once such units are established, their interruption is assumed to involve a cost (a sudden loss in value) that may counteract immediate reinforcement contingent on that interruption.

Figure 2 illustrates the design of the present experiments with pigeon subjects. At time t_1, two patterns of behavior were made available. In the present experiments these patterns were generated by schedules of reinforcement. One pattern ended with an SS reinforcer the other with an LL reinforcer. Because the patterns take time to occur, preference is predicted by Equation 1 to change from LL at t_1 to SS at t_2. The only cost of switching from one pattern to another during the interval $t_2 - t_1$ (symbolized by the dotted arrows in Figure 2) is the cost of disrupting the pattern. Ignoring this cost, pigeons would be expected to begin Pattern B but switch to Pattern A at the point predicted by Equation 1. Unlike the paradigm of Figure 1, preference for LL could be reversed at any time during the interval $t_2 - t_1$. In the present experiments, therefore, self-control was exhibited by refraining from switching from one behavioral pattern to another.

EXPERIMENT 1

METHOD

Subjects

Four experimentally naive male White Carneau pigeons were maintained at approximately 80% of their free-feeding weights by additional feeding, if necessary, at the end of each experimental session. The pigeons were housed individually in a colony room where they were provided continuous access to grit and vitamin-enriched water.

Apparatus

Experimental session were conducted, individually, in a standard pigeon conditioning chamber. The chamber was a sealed plywood enclosed box with aluminum walls and ceiling and a wire-mesh floor. A fan provided continuous circulation of air into the chamber. The experimental space was 29.6 cm wide by 32.5 cm deep by 30.5 cm high. The front wall contained three translucent response keys (2.5 cm diameter) mounted 22.2 cm above the floor and 7.5 cm apart, edge to edge (only the left and right response keys were used in Experiment 1). Miniature lamps (No. 1829 bulbs operating at 24 V) with plastic covers illuminated the response keys. Access to a solenoid-operated grain hopper was available through a circular opening (5 cm diameter) located 2.5 cm above the floor directly under the middle response key. During food deliveries, the hopper was illuminated by two No. 1829 bulbs operating at 24 V. The entire chamber could be illuminated by two No. 1829 bulbs located at approximately the center of the ceiling. Data recording and scheduling of experimental events were controlled by an IBM® computer with Conman® software.

Procedure

All subjects were trained to eat from the grain hopper during the first 2 days of training. On the 1st day, the hopper was overfilled and kept in a raised position until the pigeon ate all the grain. On the 2nd day, the hopper was lowered and raised repeatedly (up 30 s, down 30 s) for a total of 30 cycles. Beginning on the 3rd day, the pigeons were trained to peck keys using a modified autoshaping procedure in which the center keylight was illuminated white for 4 s after which, 0.5 s later, the food hopper was raised and illuminated for 6 s. There followed a variable intertrial interval (ITI) averaging 30 s, during which the chamber was dark. A key peck during the 4-s trial produced immediate food presentation (reinforcement). After four consecutive key pecks, the autoshaping procedure was replaced by a continuous reinforcement (CRF) schedule with the same ITI. This change occurred during the ITI. The session ended after 36 responses with the CRF schedule. In subsequent sessions, responses were reinforced for 36 trials according to a CRF schedule for one session, a variable ratio of two responses (VR 2) for two sessions, a VR 5 schedule for three sessions, and finally a VR 10 for four sessions. In each, a variable-interval 30-s ITI was present. This concluded preliminary training.

In all conditions of the experiment, subjects were presented with green and red keys alternated randomly from side to side on each trial. For 2 subjects, the red key was always associated with 2.5 s of food access delayed by 0.5 s (SS) and the green key was always associated with 4.5 s of food access delayed by a 3.5-s blackout (LL). For the other 2 subjects, the colors were reversed. To keep both alternatives equal in total trial time, a 5-s blackout was imposed after SS reinforcement.

In the baseline procedure (Conditions 1, 3, 5, and 7), the pigeons chose between SS and LL by pecking once on either key (concurrent CRF schedules of reinforcement). To

Table 1

Proportion of SS reinforcers obtained over the last five sessions in Experiment 1.

	S32		S33		S34		S35	
Condition	Number of sessions	SS Preference	Number of sessions	SS preference	Number of sessions	SS preference	Number of sessions	SS preference
1 CRF	15	.97	15	.78	15	1.00	15	.43
2 FR 31	40	.47	40	.44	16	.26	17	.26
3 CRF	15	.99	15	.88	15	.98	15	.25
4 SigFR 31	29	.56	22	.59	38	.60	15	.29
5 CRF	15	.99	15	.88	15	.99	15	.38
6 FI 30	15	.73	40	.48	15	.76	25	.32
7 CRF	15	1.00	15	.91	15	1.00	20	.92

ensure contact with both outcomes, 12 forced-choice (i.e., only one key lit and operative) trials (six SS and six LL in random order) preceded the experimental trials. An experimental trial consisted of a subject making a choice by pecking either the SS or the LL key, after which both keylights were darkened and the outcome obtained. After LL or the 5-s blackout (if the subject had chosen SS) a fixed 30-s ITI was imposed, during which, with the keylights off, only a white houselight was illuminated. After 30 s, the houselight was turned off and the keylights were illuminated. A session ended after 45 experimental choice trials.

Condition 2 (FR 31) differed from the baseline condition in two respects: First, the concurrent CRF schedules were replaced by concurrent FR 31 schedules in which pecks on either key counted towards fulfillment of the FR 31 requirement. The key on which the 31st peck was made determined whether SS or LL would be obtained. Second, there was no ITI.

Condition 4 (sigFR 31) was identical to Condition 2 except that after the 30th peck, on either key, both keylights were darkened for 1 s and the white houselight was illuminated for 1 s, after which the houselight was turned off, the keylights were illuminated, and the next peck on either side was reinforced by SS or LL.

Condition 6 (FI 30) was a fixed-interval 30-s schedule in which both keylights were illuminated for 30 s. The first choice response after 30 s was reinforced by SS or LL.

The criteria for changing conditions were as follows: At least 15 sessions had elapsed, within the last five of which the same alternative was chosen on more than 50% of the trials. If after 15 sessions this criterion had not been met, that condition was continued until five successive sessions occurred in which the same alternative was chosen on more than 50% of the trials. Finally, if the above criteria had not been met within a total of 40 sessions, relative indifference was assumed and the condition was changed.

RESULTS

The data shown in Table 1 are averages over the last five sessions for each condition. Except for S35 in Condition 7, there were no significant differences in CRF responding for any pigeon from Conditions 1 to 3 to 5 to 7. The data of the four CRF conditions were averaged for each subject (including S35) in statistical calculations. Figure 3 shows mean percentage of SS reinforcers obtained over the last five sessions for each condition for each subject.

A repeated measures analysis of variance revealed a significant main effect of condition, $F(3, 9) = 12.93$, $p < .01$. Post hoc comparisons using the protected least significant difference test (Keppel, 1982, pp. 157–159) required that the difference between condition means exceed 25.53 to be significant at the .01 level. The analysis revealed significant differences at $p < .01$ between the CRF condition and the FR 31 condition, between the CRF condition and the sigFR 31 condition, and between the CRF condition and the FI 30 condition. There were some differences among the non-CRF conditions (e.g., more self-control in the FR 31 condition than in either of the other two for all subjects), but the possibility of order effects (despite return to baseline between conditions) precludes their unambiguous comparison.

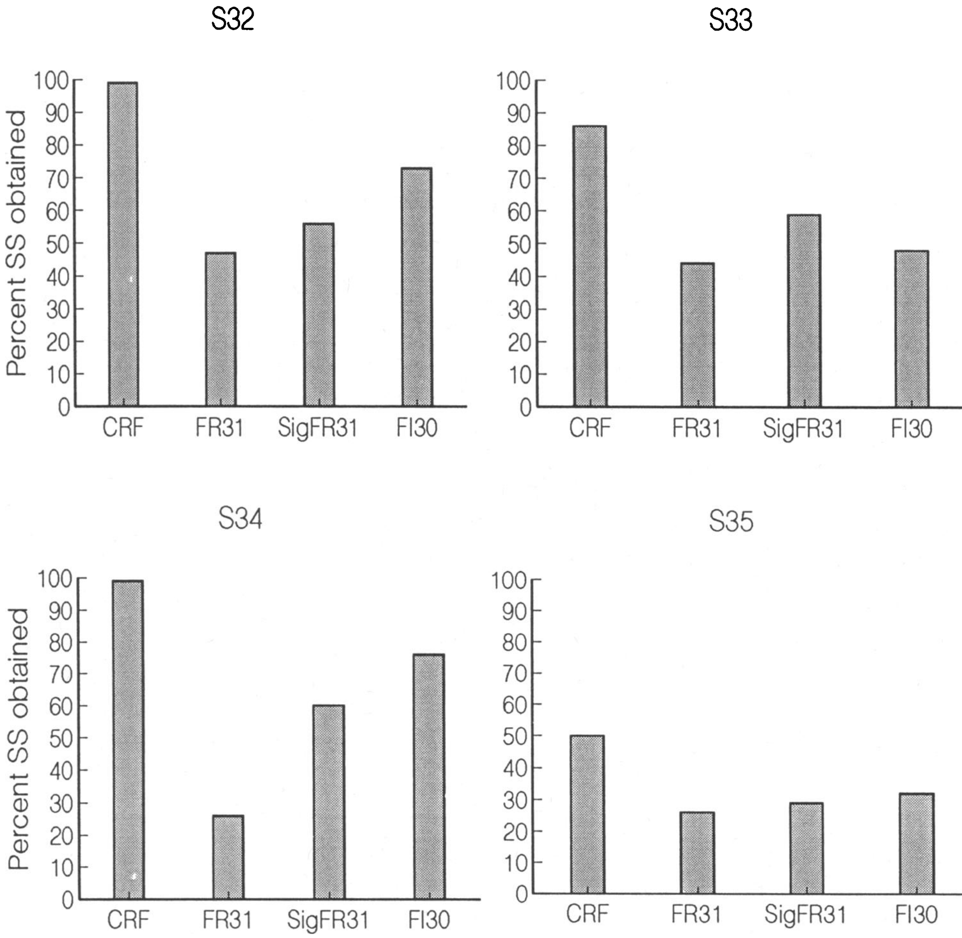

Fig. 3. Mean percentage of SS reinforcers obtained over the last five sessions for each condition for each subject in Experiment 1.

Figure 4 shows the mean SS preference as a function of position in the FR sequence for the FR 31 and sigFR 31 conditions and as a function of seconds for the FI 30 condition. The median durations of the FR sequence for the FR 31 condition for S32, S33, S34, and S35 were 22.9 s, 24.1 s, 20.0 s, and 15.6 s, respectively. The median durations of the FR sequence for the sigFR 31 condition were 29.7 s, 23.7 s, 20.3 s, and 15.0 s, respectively. The trial durations were approximately the same regardless of SS or LL reinforcement. Thus, on a strictly temporal abscissa, the FR 31 and sigFR 31 curves would be compressed by about 10 s relative to the FI 30 curve. For the sake of simplicity in reading the abscissa, 30 responses were arbitrarily normalized at 30 s.

The fact that the FR 31 and sigFR 31 curves are approximately horizontal is evidence that the initial preference (at the beginning of the ratio) was generally maintained throughout. In other words, once a subject began pecking on the LL key, it apparently continued to peck that key throughout the ratio (although it is conceivable that switches from SS to LL on some trials were exactly counterbalanced by switches from LL to SS on other trials).

The generally horizontal functions of Figure 4 indicate that with the fixed ratio (FR 31) and the interrupted fixed ratio (sigFR 31), once a pigeon began to peck on either key it tended to keep pecking on that key for the remainder of the interval (except for S34 in the sigFR 31 condition, in which the tendency was less marked). More conclusive ev-

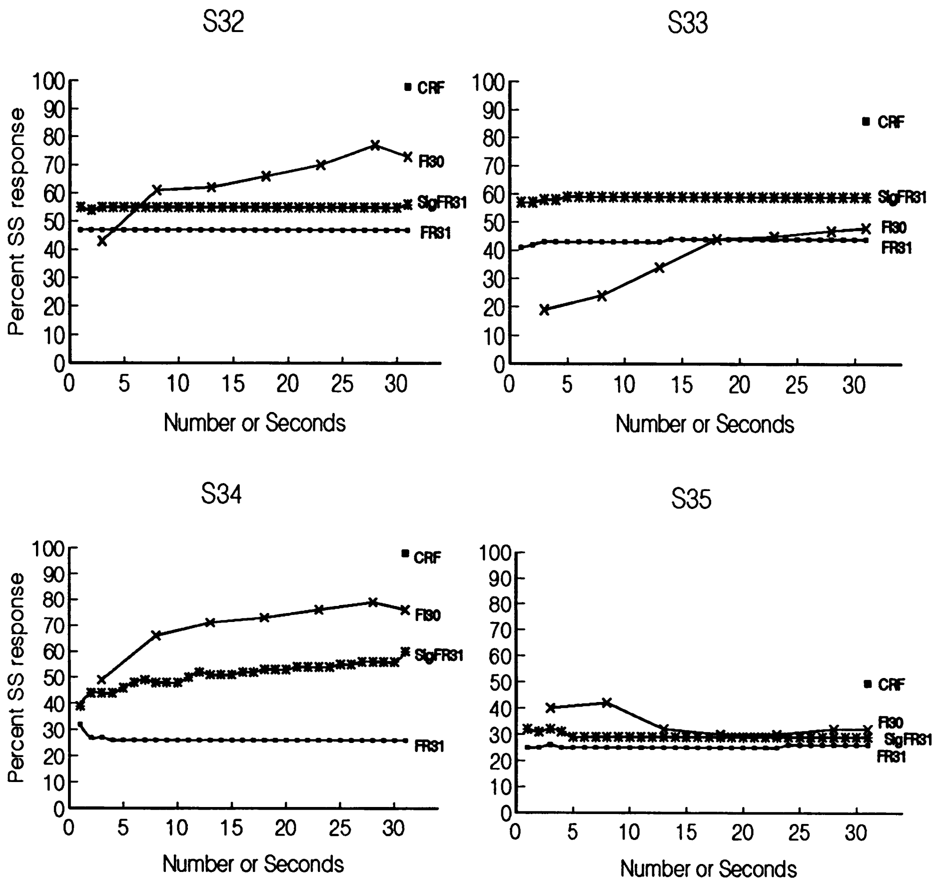

Fig. 4. Percentage choice of the SS alternative (impulsiveness or lack of self-control) as a function of response number during the FR 31 and sigFR 31 conditions and as a function of seconds elapsed during the FI 30 condition. The square at the upper right indicates percentage of SS choices in the control (CRF) condition. Data are averages of the last five sessions for each condition for each subject.

idence to this effect is the conditional probability of pecking the SS key once the LL key had been pecked. For the FR 31 schedule, the probabilities of an SS peck on the very first peck of the ratio for S32, S33, S34, and S35 were .47, .41, .29, and .25, respectively. But during FR 31 once the first peck was made on LL, the probabilities of the second peck being on SS were, respectively, .01, .00, .02, and .00. Given that a pigeon had made six successive pecks on the LL key, the probability of an SS peck on the seventh peck was zero for all 4 pigeons. Thereafter during FR 31, only an occasional defection from the LL pattern was observed.

In the FI 30 condition (Condition 6), on the other hand, only 1 subject (S35) maintained a coherent preference over time. The other 3 subjects began the interval preferring LL but shifted towards SS as the interval progressed. Nevertheless, the difference in self-control (obtained LL reinforcers) between the FI 30 and the CRF conditions was statistically significant for all pigeons.

It is conceivable that the upward-sloping FI functions of Figure 4 might actually consist of the sum of a series of horizontal functions. A pigeon could begin to peck early or late in the interval. If a pigeon began to peck early in the interval it could begin on the LL key and not defect; if the pigeon began to peck late in the interval it could begin on the SS key and continue pecking on that key. The FI functions in Figure 4, picking up both early-beginning and late-beginning intervals, would then appear to show defections where actually none existed. The point in the interval at which pigeons started to peck was not measured for the functions of Figure 4. Consequently, after Experiment 2, a supplementary FI condition (followed by a return to CRF) was imposed specifically to take these measurements. The overall results were similar to those in Figure 4 and are not shown here. Taking separately those intervals in which the third peck was made early in the interval (between the 5th and 10th seconds) and those intervals in which the third peck was made late in the interval (between the 20th and 25th seconds), the percentages of pecks on the SS key by S32, S33, S34, and S35 when they began to peck early in the interval were 49%, 42%, 87%, and 32%, respectively; the percentages of pecks on the SS key when they began to peck late in the interval were 51%, 51%, 71%, and 43%, respectively. If the upward-sloping FI 30 condition lines were indeed the sum of low and high horizontal functions, the late-beginning percentages should have been significantly higher than the early-beginning percentages. The difference between early- and late-beginning functions was not statistically significant for any subject. For S34, preference for SS was actually lower when it began pecking late in the interval than when it began pecking earlier. Thus the general upward slope of the FI functions of Figure 4 for S32, S33, and S34 is probably due to defections from the LL key as the interval progressed.

Another measure taken during the supplementary FI condition was the absolute local response rate on the SS and LL keys. (Absolute local response rate is the number of pecks on a key divided by time spent pecking that key; time spent pecking a key is cumulative time between changeovers to a key and changeovers away from the key.) The local SS rate was higher than the local LL rate for all pigeons at most points during the interval. Thus, when a pigeon defected from the LL to the SS key, it changed not only its place of responding but also its rate of responding.

As Table 1 shows, across the 4 pigeons and the four replications of the CRF condition, the median preference for the SS alternative was 95% of the choice trials. A preference for SS of 50% would thus represent a distinct improvement in self-control. Because the key colors shifted randomly from side to side in the present experiment, a degree of self-control would be attained by exhibiting a side bias—a pattern of responding on one key (either the left or right) extended across trials. In fact, especially during the first few sessions of each experimental condition, all of the pigeons in one condition or another developed strong side biases that tended to diminish as the experiment progressed. This is demonstrated most clearly by S35. That subject was strongly biased toward the right key in the first CRF condition (61% responses on the right) obtaining 57% LL reinforcers. S35 was even more strongly biased in the third CRF condition (75% responses on the right), obtaining 62% LL reinforcers, as opposed to very poor self-control for the other pigeons. However, by the final CRF condition, S35 was obtaining SS on 92% of the trials—not much better than the other pigeons—and, of course, lost the side bias (49.7% of responses to the right side).

One means of measuring preference independent of side bias is to examine preference for LL and SS only on the less preferred side. For instance, although a pigeon might obtain, say, 55% LL and 45% SS reinforcers overall by pecking, say, the left key 90% of the time, it could conceivably obtain LL on all of the 10% of the trials when the right (less preferred) key was chosen. The resultant 55% preference for LL might then be interpreted as a very strong preference for LL, overcome by a very strong left-key side bias. However, when this unpreferred-side analysis was performed for S35, in all conditions, the unpreferred side preference was about the same as the overall preference. This indicates that S35's strong side bias emerged as a consequence of a fundamental indifference between the alternatives. (To put it colloquially, if a pigeon is indifferent between the alternatives signaled by key colors, it might as well ignore them and just peck on its preferred side.)

Discussion

The soft commitment provided by engaging in a pattern of behavior was strong enough to obtain the LL reinforcer. All pigeons obtained LL on a significantly higher percentage of trials with an extended behavior pattern than they did without such a pattern. This difference occurred regardless of whether the pattern was caused by a simple ratio (FR 31), an interrupted ratio (sigFR 31), or an interval (FI 30) schedule.

It is our contention that the effective bridge between the creation of a pattern of behavior and self-control is the cost of switching to another pattern, instantiated in the present case by switching keys within a trial. In other words, the availability of two patterns leading to the two alternatives forced the subject to make a choice early in the sequence, at a point when LL was preferred. Later, the cost or difficulty or simple inconvenience of switching in midpattern was enough to overcome preference reversal. Against this contention it may be argued that the behavioral pattern itself somehow generates or preserves an underlying preference for LL.

Some evidence against this alternative conception has been obtained by Eisenberger, Carlson, and Frank (1979). They found that high-effort responding, as programmed by increased ratios on a central manipulandum (or increased length of a central alley), where only one pattern of responding was possible and switching was unnecessary, had no effect on self-control (measured by LL choice) when the central manipulandum was withdrawn and side manipulanda (SS and LL) were made available (or at the choice point at the end of the central alley). The purpose of Experiment 2 was to replicate Eisenberger et al.'s results in the present context and to study the effects of pattern interruption on self-control.

EXPERIMENT 2

METHOD

Subjects

The 4 subjects from Experiment 1 participated in Experiment 2. Weight and housing of the pigeons were identical to that of Experiment 1.

Apparatus

The apparatus for Experiment 2 was identical to Experiment 1 except that a third key, centered between the other two, was occasionally lit and operative.

Procedure

In all conditions, a subject was presented with a terminal choice between a smaller, more immediate reward and a larger delayed reward randomly alternating on the left and right side keys. The key colors were red and green. For 2 subjects, the red key was always associated with 2.5 s of food access delayed by 0.5 s (SS) and the green key was always associated with 4.5 s of food access delayed by 3.5 s (LL). For the other 2 subjects, the colors were reversed. To keep both alternatives equal in total trial time, a 5-s blackout was imposed after reinforcement of the SS choice. The colored keys were consistent for all subjects throughout Experiments 1 and 2, as were the reward amounts associated with the SS and LL alternatives.

The five types of conditions of this experiment are diagrammed in Figure 5. In all conditions, 12 forced-choice trials preceded experimental trials. In the CT 30 condition, an experimental trial began with only the center key illuminated with white light; subjects pecked 30 times on that key before the terminal choice. After 30 pecks, the center key was darkened and the left and right keys were illuminated. After a peck on either the SS or LL key, the SS or LL outcome was obtained. If SS had been chosen, the next trial began immediately after the 5-s blackout had expired. A session ended after 45 trials.

The other conditions had three components: an initial component with some number of side-key responses, a middle component with an illuminated center key, and a final component with side-key responses. In all conditions the SS or LL outcome occurred after the 31st peck overall. Criteria for changing from condition to condition were the same as in Experiment 1 with one exception. In the case in which a consistent strong side bias was present (over 90% responses to one side), relative indifference was assumed after 20 sessions. The order of conditions was CT 30, CT 10, CT 1, CT 3, CT 6, and CT 30.

RESULTS

Figure 6 shows mean percentage of SS reinforcers obtained over the last five sessions for each condition for each subject. All subjects demonstrated a strong preference for the SS alternative in both CT 30 conditions

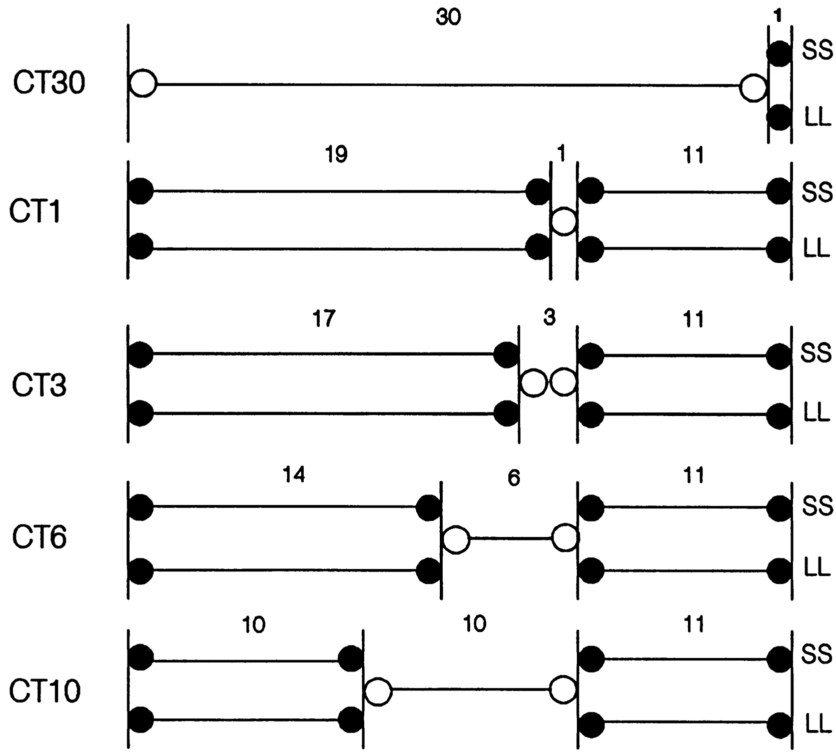

Fig. 5. Conditions of Experiment 2. Distances between joined circles represent number of responses. The filled circles are choice responses; the unfilled circles are center-key responses. The number of responses for a segment is indicated directly above the segment.

(first and last). There was no significant difference for any subject between the first and second CT 30 conditions; therefore, the arithmetic mean was calculated for each subject and used in statistical calculations. Each subject was exposed to each condition for 15 sessions (within which the stability criterion was reached) with the following exceptions: for S32, 27 sessions of Condition 4 and 20 sessions of Condition 5; for S33, 20 sessions of Condition 4 and 20 sessions of Condition 5; for S34, 30 sessions of Condition 3 and 20 sessions of Condition 4; for S35, 18 sessions of CT 30 (Condition 1) and 20 sessions each for Conditions 2 through 5.

Comparing the CT 30 condition of this experiment (Figure 6) with the CRF condition of Experiment 1 (Figure 4), it is evident that all subjects obtained SS as frequently or more frequently; that is, they were equally or more impulsive when making 30 pecks on a central key as they were without any response requirement. This result replicates the finding of Eisenberger et al. (1979) that effort or patterning per se does not affect temporal self-control.

A repeated measures analysis of variance revealed a significant main effect of condition, $F(4, 12) = 4.99$, $p < .05$. A planned comparison between the CT 30 condition and the combination of the interruption conditions revealed an overall statistically significant decrease in SS preference in the interruption conditions, $F(1, 3) = 16.72$, $p < .05$. Post hoc comparisons between the CT 30 and the individual interruption conditions were made using the least significant difference test and required that the difference between condition means exceed 18.8 to be significant to the .05 level and exceed 27.04 to be significant at the .01 level. The analysis revealed significant differences at $p < .01$ between the CT 30 condition and both the CT 3 and CT 6 conditions. The difference between the CT 30 condition and the CT 1 condition was significant to $p < .05$. The difference between

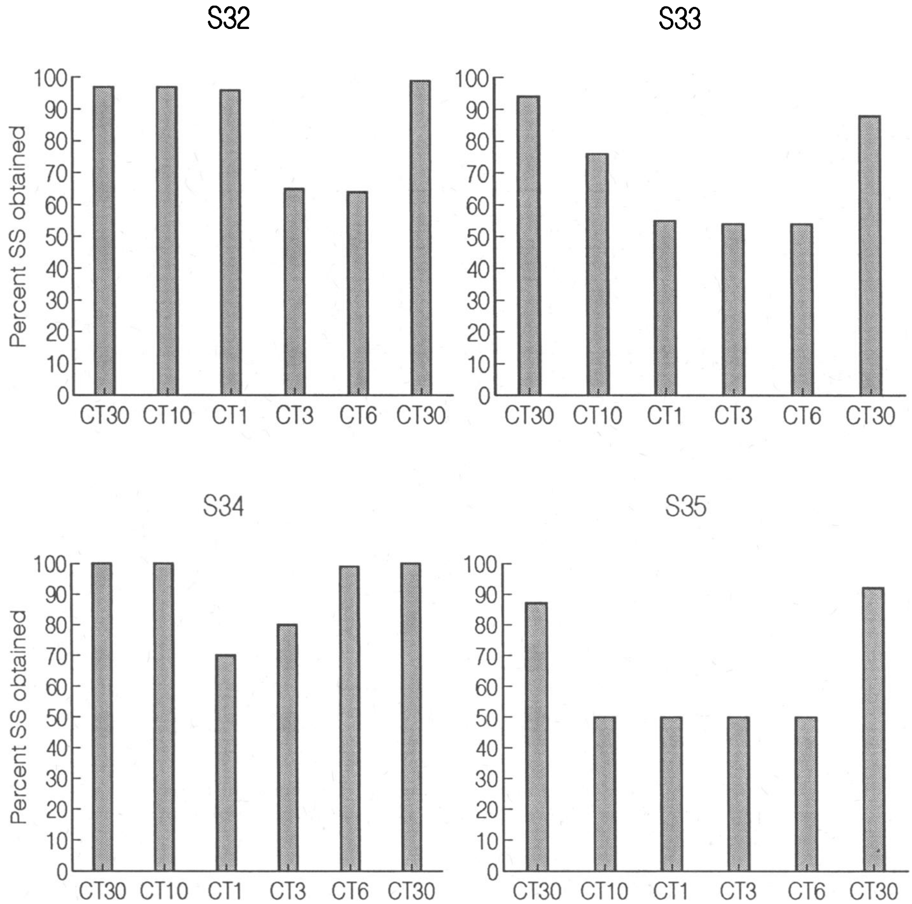

Fig. 6. Mean percentage of SS reinforcers obtained over the last five sessions for each condition for each subject in Experiment 2.

the CT 30 condition and the CT 10 condition was not statistically significant ($p < .13$). The possibility of order effects precludes meaningful comparisons among the nonbaseline (non-CT 30) conditions.

Figure 7 shows the response patterns of the 4 pigeons for the CT 1 condition. (Patterns in the CT 3, CT 6, and CT 10 conditions were similar.) The left branch shows SS choice prior to the illumination of the center white key. The right branch shows SS choice after termination of illumination of the center white key. The figure shows that for S32 and S34, SS preference was not flat prior to center-key illumination but rather increased as the interruption approached. For S33 and S35, SS preference before the interruption was generally flat. After the interruption, SS preference of all pigeons was flat and at a higher level than before the interruption. The flatness of the after-interruption curves indicates that once a pigeon began pecking on a key after the interruption, it tended to keep pecking that key. This was true even though, according to Equation 1, the value of SS relative to LL is greater the closer in time to the outcome.

Discussion

As in Experiment 1, the pigeons could obtain LL during the CT 30 conditions (first and last) more frequently than they actually did simply by means of a strong side bias. S35, which was strongly side biased in Experiment 1, also showed very strong side biases in this experiment (98%, 96%, 99%, and 99% preference for the left key in Conditions CT 1, CT 3, CT 6, and CT 10, respectively). S33 also

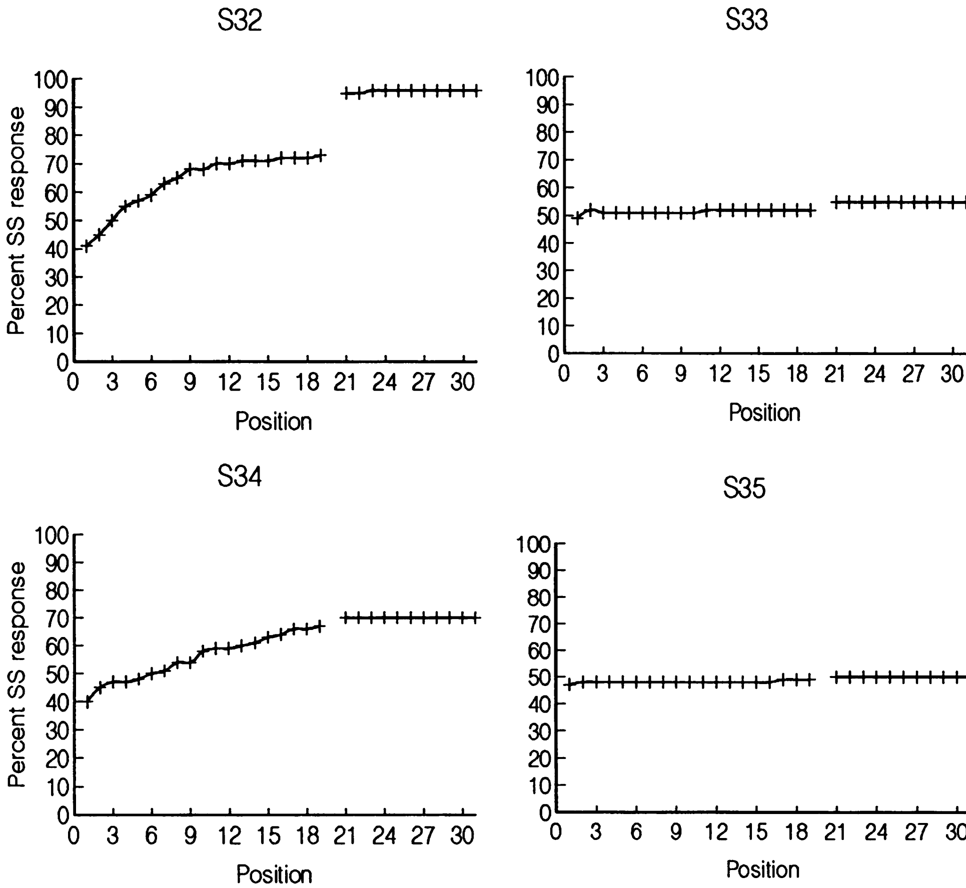

Fig. 7. Response patterns for the CT 1 condition. The left branch shows percentage SS choices prior to the center-key response as a function of response number. The right branch shows percentage SS choices after the center-key response.

showed strong side biases (97%, 92%, and 86% in Conditions CT 1, CT 3, and CT 6). These biases were so strong that it was not possible to analyze meaningfully the few responses to the less preferred side, as was done in Experiment 1. From results of Experiment 1 and the other conditions, it may be inferred that the biases were not a means to achieve self-control. The biases could have arisen due to indifference between the FR 11 alternatives immediately postinterruption, paired with coherence of the FR 11 pattern. This inference follows from the fact that both pigeons returned to very strong preference for SS when CT 30 was repeated (last condition). Had the side bias been a means of achieving self-control, it would have been as effective in the CT 30 condition as in the others.

CONCLUSION

The constraint that keeps pigeons from switching from a response pattern leading to LL to a response pattern leading to SS (from Pattern B to Pattern A of Figure 2) seems to be the cost of an overt switching response. This cost may immediately oppose the heightened value of the SS alternative as its delay decreases. The increased flatness of the preference functions of Experiment 1 and Experiment 2 indicates that as the pattern progresses the cost of disrupting it increases, so much so that the increasing value of SS is completely overwhelmed. Thus, although the commitment achieved by beginning a response pattern may be said to be soft, in the sense that its disruption is possible, it is nevertheless quite effective as a means of self-control.

In the present experiments the LL and SS reinforcers were nominally extrinsic to the schedules by which they were obtained. But each schedule and reinforcer together may be conceived of as a response unit with its own intrinsic value. Premack (1965) argued similarly in accounting for the reinforcing power of electrical brain stimulation (EBS). (According to Premack, although EBS itself involves no apparent consummatory response, the instrumental response and the EBS together form a valuable unit that then acts like the eating mechanisms to reinforce instrumental acts that the unit is contingent upon.) Self-control in the present experiment was achieved first through an initial choice of the more valuable unit and second through the unit's coherence. Concatenations of this sequence—forming and enlarging valuable units and persisting through their execution—(rather than the no-less-hypothetical stringing together of conditioned reinforcers) may underlie the intrinsically reinforced patterns of human life we call "health," "social responsibility," "creativity," "morality," and so forth.

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