THE CONTROL OF SWITCHING INTO BLACKOUT DURING EXTINCTION¹

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During the extinction component of a multiple variable-interval extinction schedule, four pigeons learned to peck a second key that switched off the keylights. Two experiments attempted to isolate the events that control this behavior. In the first experiment, switching into blackout was equally maintained when switches were restricted to the first minute as when they were restricted to the last minute of the extinction component. When switches could be emitted in the first and last minutes, they occurred more frequently in the first. Restricting switching to the first minute of each component and eliminating the blackout between components had no effect on switching. In the second experiment, when the stimulus correlated with extinction was omitted, switching decreased slightly. Omission of both multiple schedule stimuli decreased the switching rate, but switching was still maintained. Food reinforcement was then omitted and switching by two birds increased. Switching ceased when blackout was no longer the consequence of pecking the switching key. It was concluded that switching was not controlled by the similarity of the blackouts produced by the switching key and those that occurred between components; nor was it maintained by the temporal proximity of switching responses to the onset of the reinforced component. Finally, switching did not appear to be controlled by the main-key stimuli correlated with the components of the multiple schedule.

In a multiple schedule, two or more stimuli alternate and each is associated with a schedule of reinforcement. Three studies have been reported in which a second response was available to an animal working on a multiple schedule. The second response switched off the stimulus associated with the schedules for a period of time and it came to be consistently emitted during the component providing the lower reinforcement rate. This switching has been interpreted as an escape response emitted under the aversive control of the stimulus associated with the component providing the lower reinforcement rate (Rilling, Askew, Ahlskog, and Kramer, 1969; Rilling, Kramer, and Richards, 1971; Terrace, 1971). The rate of such switching responses has been suggested as a measure of the aversiveness of the stimulus signalling the component with the lower rate of reinforcement.

Rilling *et al.* (1969) showed that such switching responses occurred at a high rate when they turned off the schedule-associated stimuli, and at a low rate when pecking the switching key had no consequence. Switching was more frequent when the multiple schedule was composed of variable-interval (VI) 30-sec and extinction (EXT) than when it was composed of VI 30-sec and VI 5-min. Removing the VI 30-sec component entirely, *i.e.*, reinforcement and its correlated stimulus, decreased the rate of switching for two of four birds. Rilling *et al.* (1969) concluded that the stimulus that signals a lower rate of reinforcement functions as a conditioned aversive stimulus.

Explanations for the maintenance of the escape response, which have been considered but rejected, include extinction-produced variability, displaced aggression, stimulus change, and frustration-produced activity (Rilling *et al.*, 1969; Terrace, 1971). However, other explanations seem possible. Switching out of an extinction stimulus could be maintained by the intermittent presentation of the intertrial interval and the discriminative stimulus for reinforced responding at the end of the switch-out period. Such an explanation is not sup-

¹Based on a doctoral dissertation to be submitted by the first author. This research was supported in part by University Grants Committee grants AG 141 PSY 7 to the first author, and grant AG 140 PSY 14 to the third author. Reprints may be obtained from Guy von Sturmer, Department of Psychology, University of Auckland, Private Bag, Auckland, New Zealand.

ported by the fact that switching is more frequent at the beginning of the extinction component than at the end (Rilling *et al.*, 1969; Terrace, 1971), but the few switches emitted at the end of the extinction component could be critical in the maintenance of switches throughout the component. The first experiment examined the possibility that switching was maintained by such contingencies. Switching could also be maintained because its stimulus consequences resembled the stimuli during the interval between components in the multiple schedule. This was also tested in the first experiment. When it was found that these possibilities were not likely, a second experiment was carried out to assess the contributions to the maintenance of switching behavior made by various stimuli associated with both components.

EXPERIMENT I

METHOD

Subjects

Four homing pigeons were maintained at $80\% \pm 4\%$ of their free-feeding weights. They were numbered 1009 to 1012.

Apparatus

All experimental events were controlled by electromechanical equipment remote from the soundproofed and ventilated experimental chamber, whose dimensions were 320 mm high by 340 mm deep by 310 mm long. There were three 20-mm diameter keys 110 mm apart and 250 mm from the mesh floor. The forms and hues with which the keys were transilluminated were controlled by digital display units. The grain magazine was reached through a 50-mm square aperture below the center key. A white light illuminated the magazine when it was operated. The keylights and the magazine light were the only sources of illumination in the chamber.

Procedure

At the start of the experiment, the subjects had extensive histories of responding on multiple schedules with the option of switching out of both the EXT and the VI components. The procedures that had been used included a condition in which responses to the switching (right-hand) key turned off a VI schedule

or an EXT schedule but not the light on the switching key, and various conditions of blackout duration, and of schedules in the reinforcement components. Switching was not maintained when the switching key was lit while the center key stimulus was switched off; nor was switching well maintained when the blackout duration was 1.5 sec, rather than 7.5 sec or 30 sec. Reinforcement in both the present and the previous experiments consisted of 3-sec access to wheat, and supplementary mixed grain was given when necessary after each 63-min training session. Training was conducted five days of the week.

In the multiple schedule, the 3-min components, together with their associated stimuli, were presented alternately. Components were separated by a 10-sec blackout, during which all responses were ineffective and all lights were off. During the VI component, the center key was illuminated green and bisected vertically by a 3 mm-wide white line, and a VI 30-sec schedule was in effect for responses on that key. During part of this time, the switching key was illuminated white and each response to this key was followed by a 30-sec period in which neither key was illuminated and responses on both keys were ineffective. During the extinction component, the center key was illuminated plain green and responses to that key were not reinforced. The contingencies for responding to the switching key were the same as during the VI component. These main-key stimuli constituted a reversal of those associated with the VI and EXT components in all previous conditions. The production of blackouts did not stop the timers controlling component durations, the VI schedule, or the intertrial interval. Thus, blackouts consequent upon switching responses initiated during the last 30 sec of a component were continuous with the intertrial interval (also blackout), but did not affect the duration or time of onset of the following component.

It was reasoned that, if escape from the extinction stimulus was maintained by the occasional appearance of the VI stimulus, then switching might be better maintained when the side key was available only in the last minute of the 3-min EXT component, than when switching was available only in the first minute of EXT. The availability of the switching key was signalled by the illumination of this

key by white light. Fifteen sessions were given in which the switching key was available only during the third minute of the VI and EXT components of the multiple schedule. This was followed by 15 sessions in which switching was possible only during the first minute of each component, then 25 sessions when the switching key was again available only during the third minute.

The next part of this experiment was intended to check the finding of Rilling *et al.* (1969) and Terrace (1971) that switching occurred mainly towards the beginning of the EXT component. Ten sessions were given in which switching was available throughout the VI and EXT components. Then, another 10 sessions were given in which switching was available only in the first minute and the last minute of each component. The response was not available in the second minute because switches at the end of the first minute would decrease the opportunities for switches to occur in the second minute, and switches during the second minute would similarly interfere with opportunities during the third minute. Finally, in Experiment I the birds were trained for 15 sessions in which switching was available only in the first minute of both components and there was no 10-sec intercomponent blackout. This condition was designed to investigate whether switches into blackout were controlled by the similarity of the switch-dependent blackout to the intercomponent blackout.

RESULTS

The relative number of main-key responses was calculated for each bird in each session (VI/VI + EXT). Bird 1009 maintained a stable discrimination level of 0.85 or greater from the seventh session. Birds 1010 and 1011 did not deviate below 0.90 from Sessions 6 and 4 respectively, and Bird 1012 rarely failed to exceed 0.85 from the fourth session. Because switching responses within 30 sec of the end of a component were not recorded separately from those when 30 sec or more of a component was yet to run, it was not possible to calculate a discrimination index that took account of variations in availability of the main key due to switching. However, the minor session-to-session fluctuations in discrimination performance did not relate to any of the experimental treatments. Data on switching into

blackout during both components appear in Figure 1. Of the first 55 sessions, the first 15 comprised the condition in which switches could be made only during the third minute of each component. In the next 15 sessions, switches were possible only during the first minute of each component, and in the last 25 sessions, switching was again possible only in the final minute of each component. The results show very few consistent effects of these manipulations. It can be seen, however, in these and in all later data that switching occurs predominantly during the EXT component.

During Sessions 56 to 65, switching was possible during all three minutes of each component; during Sessions 66 to 75, switches were available in the first and last minutes but not in the middle minute. It can be seen that switches tended to be emitted near the beginning of the EXT component.

In the final 15 sessions of Experiment I, switching was allowed only during the first minute of each component and there was no intertrial interval or intertrial blackout. In three birds, switching was maintained during the EXT component.

DISCUSSION

The results of Experiment I do not support the hypothesis that switching out of the EXT component into blackout in multiple VI EXT schedules is maintained by the adventitious production of the VI component or stimuli with which it is associated. Switching was not reliably affected by confinement to either the first or the last minutes of the components, and pecks on the switching key were still maintained when a response-produced blackout in the EXT component was always followed by at least 1.5 min of the EXT component and intertrial blackouts were not scheduled. This experiment does not, however, entirely rule out the possibility that the blackout consequent upon switching became a conditioned reinforcer due to eventual restoration of the VI stimulus; but the fact that switching was more frequent at the beginning of the EXT component than at the end makes such a view difficult to sustain. The data are consistent with an explanation in terms of escape from a stimulus that has acquired aversive properties (Rilling *et al.*, 1969; Rilling *et al.*, 1971; Terrace, 1971).

Fig. 1. Each section shows timeouts during both components of the multiple schedule. The heading over each section indicates when the switching key was available.

EXPERIMENT II

If the switching in Experiment I were under the aversive control of the key stimulus signalling the EXT component, it would follow that switching would cease if the key stimulus associated with the EXT component were removed from the multiple schedule. Experiment II investigated this and also assessed the extent to which the stimulus associated with

reinforcement, reinforcement itself, and black-out alone, controlled the switching response.

Subjects and Apparatus

The subjects and apparatus were the same as in Experiment I.

Procedure

The procedure was in general the same as in Experiment I. However, between the end of

Experiment I and the beginning of Experiment II, there were 25 sessions in which a scheduling error was made such that pecks on the switching key during the third minute of each component were ineffective. This resulted in a marked decrease in responding, so, to bring switching back to its normal rate, Experiment II began with 15 sessions in which the scheduling defect was remedied and the stimuli associated with the VI and EXT components were reversed. In all conditions in Experiment II, switching was available at all times in both components and, except during the final 20 sessions, switching always produced a blackout that terminated at 30 sec or the end of the component, if that was sooner. An intercomponent blackout of 10 sec was again arranged and the schedules were again multiple VI 30-sec EXT. It was also arranged that the tape timing reinforcements would stop during response-produced blackouts in the VI component. This was to avoid the possibility of switching being maintained by reinforcement being set up at the end of response-produced blackouts in the VI component.

Following the 15 sessions of discrimination reversal training, there were 30 sessions in which the stimulus correlated with the EXT schedule (a green key with a white vertical line) was not presented during the EXT component. During that component, only the switching key was illuminated and operative. About half way through this first treatment, Bird 1011 became ill and was withdrawn from the experiment.

In the next 20 sessions, the stimulus correlated with the VI component was also removed and a response-independent VI 30-sec schedule of reinforcement was in effect during the VI component. The center key was dark and inoperative at all times, and during both components, only the switching key was illuminated. The only consequence of switching responses, apart from stopping the reinforcement tape when they occurred in the VI component, was to turn off the switching key itself for 30 sec.

Following this treatment, there were 15 sessions during which reinforcement was no longer delivered. The switching key was available in both components and the components were identical in all respects.

Finally, there were 20 sessions during which

the 30-sec blackout contingency on the switching key was removed. The switching key was always illuminated, except during the 10-sec noncontingent intercomponent blackout, and pecks on the switching key had no effect.

RESULTS

Figure 2 shows the re-establishment of the switching performances during the 15 sessions of discrimination reversal training. The main-key discrimination was re-established by the sixth session in all birds. During the next 30 sessions, when the stimulus associated with the EXT component was no longer presented, the rate of switching decreased only slightly in the EXT component and remained almost absent in the VI component. In the next phase of the experiment, omission of the stimulus correlated with the VI component resulted in a transient increase in switching rate in both components, followed by a substantial decrease; but the response was still maintained. Food reinforcement was then omitted and the rate of switching into blackout increased during the VI component in three birds and in the EXT component for two birds. Finally, when blackouts were no longer arranged as the consequence of pecks on the switching key, the rate of pecking the switching key increased transiently in two birds and then dropped to virtually zero in all three.

DISCUSSION

Experiment II showed that switching into blackout during the EXT component of a multiple VI EXT schedule was not a measure of the aversiveness of the arranged key stimulus associated with the EXT component. Switching survived 30 sessions during which that stimulus was never presented and could, therefore, never be escaped. It could be argued that switching was maintained by the removal of another stimulus that was unique to the EXT component—the switching key stimulus when it appeared alone, as distinct from when it appeared with the VI stimulus on the center key during the VI component. However, in the next part of the experiment, the stimulus associated with the VI component was also omitted for 20 sessions. With both the center-key stimuli associated with the components of the multiple schedule omitted, the animals were on a mixed schedule, and the only bases for discrimination between the components

Fig. 2. After baseline training, first the stimulus correlated with extinction was discontinued, then the VI stimulus was also eliminated. In the fourth section, presentation of grain also ceased and, finally, pecks on the switching key had no consequences.

were their temporal alternation and the presentation of grain. Apparently because of this, switching occurred frequently at first during both components, and resulted in a lower rate of grain presentation when it occurred during the VI component. Although switching was maintained through this part of the experiment, it did occur at a lower rate than previously and this might be attributed to the initially lowered reinforcement rate consequent upon switching during the VI component.

In the next part of Experiment II, grain presentation was discontinued, however, and the rate of switching generally increased. It is possible that, if adventitious grain reinforcement were involved in the maintenance of switching, the behavior could repeatedly occur after grain presentation had ceased (Neuringer, 1970), but this hypothesis is hard to reconcile with the higher frequency of switches at the beginning of the EXT component found in Experiment I. In the final part of Experiment II, the elimination of blackout as a consequence of pecks on the switching key, switching was no longer maintained. Its vir-

tual disappearance from the record was preceded, in two birds, by a transient increase of the sort typically observed at the onset of an extinction procedure. Plainly, switching was largely under the control of its immediate consequence, the complete darkening of the experimental chamber during periods when grain reinforcement was presented at a lower rate.

The analysis of switching can be usefully taken in two parts: the neglect by the animal of the main key, on the one hand, and on the other, the maintenance of activity on the switching key. In studies of switching during fixed-ratio (FR) schedules (Appel, 1963; Azrin, 1961; Thompson, 1964) the concept of aversive control has been used to explain *both* aspects of the behavior. Thompson (1964), for example, called timing out a "sensitive, convenient and direct procedure for measuring the concomitant aversive properties of FR schedules of positive reinforcement". Appel (1963) concluded that switching could be viewed as an escape response from some noxious aspect of the positively reinforcing FR schedule—for

example, after reinforcement when a relatively long time and large amount of work are required before the next reinforcement. The concept of aversive control, however, does not seem necessary to account for neglect of the main key, because such neglect typically occurs at times when the reinforcers that could maintain main-key activity are particularly rare. Such a view seems favoured by Zimmerman and Ferster (1964), who consider it possible that switching represents temporary losses of control by the schedule of food reinforcement. In the present study, the beginning of the EXT component would appear to be an easily discriminable occasion when main-key pecks would not be reinforced, and this was where the highest rate of switching occurred.

Concepts of aversion and escape are also insufficient, at least on their own, to account for the maintenance of behavior on the switching key. Rilling *et al.* (1969) and Rilling *et al.* (1971) suggested that the aversiveness of the stimulus that the birds were escaping derived from its association with a low reinforcement rate; but in these studies, the reinforcement rate was just as low, if not lower, during the response-dependent blackouts or timeouts as it was during the stimulus from which the animals were supposedly escaping. That is, the stimuli that the animals switched into should also have become aversive. According to Terrace (1971), conditioned aversiveness derives only from unreinforced responding in the presence of a stimulus and thus, in his view, the stimuli the animals switched into could not have acquired aversive properties. However, Rilling *et al.* (1971) found no relationship between switching and unreinforced responding. Coughlin (1973) used shock to punish main-key responses during the stimulus associated with EXT in a successive discrimination. It was expected that this would make the unreinforced stimulus more aversive and that, if timing out were really an escape response, birds in the shock groups would make more timeout responses. In fact, the birds in the shock groups switched out less than those that were not shocked. Shock did suppress responding on the main key sooner than EXT alone, and this effect continued for the groups that obtained no blackouts as a consequence of pecking the switching key. Groups that were shocked showed less behavioral contrast, however, during the reinforced component on the

main key and Coughlin (1973) used this to support the notion that the inferior performance of the shock groups on the switching key might be due to the generalization of the aversive properties of punishment for responding during the EXT component. Such an interpretation still, however, poses difficulties for an escape-from-aversiveness view of switching. Zimmerman and Ferster (1964), in a study of switching in FR schedules, reported that their birds showed little disposition to switch on occasions when the food schedule should have been most aversive.

Pecking on the switching key during periods when behavior on the main key is not maintained by the food schedule may be better explained in terms of stimulus change. Appel (1963) concluded that stimulus change was important in maintaining switching, but added that the relative reinforcing value of stimulus change was probably related to the degree of aversiveness of the baseline schedule of reinforcement. It may be more useful simply to say that it is probably related to the degree of control retained by the baseline schedule. In relation to his data, Coughlin (1973) said it could be argued that when a more powerful reinforcer—food—is withdrawn, behavior is maintained by a weaker one—stimulus change.

Terrace (1971) arranged a condition where pecks on the switching key turned off the switching keylight, but not the key stimulus associated with the schedule with the lower reinforcement rate or the houselight, and this manipulation of stimulus change failed to maintain switching. Coughlin (1973), however, found there was a greater tendency to switch when the consequence of switching was the turning off of all lights in the chamber than when switching resulted only in the offset of the keylights. Possibly, to be effective, the stimulus change must be of larger magnitude than that used by Terrace (1971) and further exploration of this parameter could be useful.

REFERENCES

- Appel, J. B. Aversive aspects of a schedule of positive reinforcement. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 423-428.
- Azrin, N. H. Time out from positive reinforcement. *Science*, 1961, 133, 382-383.
- Coughlin, R. C. Timeout from a stimulus correlated with the extinction component of a multiple schedule. *Learning and Motivation*, 1973, 4, 294-304.

- Neuringer, A. J. Superstitious key pecking after three peck-produced reinforcements. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 127-134.
- Rilling, M., Askew, H. R., Ahlsgog, J. E., and Kramer, T. J. Aversive properties of the negative stimulus in a successive discrimination. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 917-932.
- Rilling, M., Kramer, T. J., and Richards, R. W. *Aversive properties of the negative stimulus during learning with and without errors*. Paper read at Eastern Psychological Association Conference, New York, 1971.
- Terrace, H. S. Escape from S⁻. *Learning and Motivation*, 1971, 2, 148-163.
- Thompson, D. M. Escape from S^D associated with fixed-ratio reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 1-8.
- Zimmerman, J. and Ferster, C. B. Some notes on time out from reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 13-19.

Received 28 June 1973.

(Final Acceptance 16 July 1974.)