**PREFERENCE FOR SIGNED OVER UNSIGNED
SHOCK SCHEDULES: RULING OUT ASYMMETRY
AND RESPONSE FIXATION AS FACTORS**

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Experiment 1 tested whether a "symmetrical" choice procedure yields results different from those previously reported using the "unidirectional" standard changeover procedure (e.g., Badia & Culbertson, 1972). Subjects could change at any time from unsigned to signed shock by pressing a lever and from signed to unsigned shock by pressing a second lever. Results were identical to those of the standard procedure and showed that the standard procedure is fully adequate. Experiment 2 tested whether choice of high density signed shock over low-density unsigned shock (Badia, Coker, & Harsh, 1973) resulted from initial training with equal-density schedules. Subjects were trained and tested with signed shock twice as dense as unsigned shock. Three of four subjects strongly preferred the signed condition, thus ruling out carry-over and "response fixation" as alternative explanations.

Key words: signed shock, predictability, choice, preferences, lever press, rats

Several issues exist concerning the literature on preference for signed over unsigned shock schedules. Although many researchers are convinced that preference for the signed schedule is strong and reproducible (e.g., Badia & Harsh, 1977a, 1977b; Badia, Harsh, & Abbott, 1979; Harsh, 1978), others are convinced that methodological issues prevent the drawing of strong conclusions (e.g., Biederman & Furedy, 1973, 1976a, 1976b, 1977, 1979; Furedy & Biederman, 1981).

Many of these issues have been addressed elsewhere (e.g., Badia & Abbott, 1980; Badia & Harsh, 1977a, 1977b; Harsh, 1978). However, two issues require further attention. One concerns the adequacy of the "changeover" procedure as a measure of choice; the other concerns possible methodological inadequacies in a particular experiment conducted by Badia, Coker, and Harsh (1973). The present paper addresses these criticisms on logical grounds and provides two supporting experiments.

The changeover procedure and choice. As noted, some researchers have argued that the changeover procedure is methodologically unsound as a measure of choice (e.g., Biederman

& Furedy, 1976a, 1976b, 1977; Furedy & Biederman, 1981). These criticisms have raised some concern about the validity of data obtained with this procedure (e.g., Hymowitz, 1979; Marlin, Sullivan, Berk, & Miller, 1979; Safarian & D'Amato, 1978). This concern is based upon misunderstanding and may be alleviated by a brief explanation of the procedure.

Subjects are placed in an operant chamber and are exposed in sequence to each of the two conditions between which they will later choose. The two conditions are identified by different discriminative stimuli. Responses on the choice manipulandum (e.g., lever) are recorded to provide a baseline rate, and subjects remain in this training phase until the baseline data stabilize.

A changeover phase begins following training. During the changeover phase, one of the two conditions between which the subjects must choose is designated the "imposed" condition, the other the "alternate" condition. Subjects are placed in the imposed condition and given the opportunity to change to the alternate condition by pressing the lever. The alternate condition remains in effect for a fixed period of time (the "changeover period") at the end of which the imposed condition is reinstated. To remain in the alternate condition, the subject must actively reinstate it following each termination. In this way the changeover procedure repeatedly samples preference for the alternate over the imposed con-

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dition. Subjects remain in the changeover phase until responses again meet the stability criterion.

When the subject changes to the alternate condition at above-baseline rates, that condition is said to be preferred. When the subject does not change over, however, it may prefer the imposed condition, or it may be indifferent. The two possibilities may be distinguished by reversing the imposed and alternate conditions and retesting. If the subject then changes over, it is said to prefer the (formerly) imposed condition; if not, then the subject is said to be indifferent.

When this reversal strategy is used, the procedure as a whole is sometimes referred to as a "symmetrical" changeover design (e.g., Biederman & Furedy, 1979; Furedy & Biederman, 1981; Safarjan & D'Amato, 1978). The symmetrical (sequentially bidirectional) procedure is held to be superior to the "asymmetrical" (unidirectional) procedure by these investigators. The arguments given to support this conclusion are examined next.

Confounding and the changeover procedure. Some investigators argue that the changeover procedure confounds choice of the alternate condition with other variables such as response bias and stimulus change (Biederman & Furedy, 1976b, 1977, 1979; Furedy & Biederman, 1981). This argument rests on the assumption that changeover responding indicates preference for the alternate condition and not responding indicates preference for the imposed condition. It follows that choosing the alternate condition requires a response and produces a change of correlated stimuli, whereas "choosing" the imposed condition does not; that is, both response requirement and stimulus consequence differ for the two choice alternatives and confound preference. However, as noted, the assumption is incorrect; to assess preference for the imposed condition it is necessary to add a reversal phase. Assessing preference for alternate over imposed condition and vice versa thus both require an identical, active response and produce a change of correlated stimulus. Preference is therefore not confounded by these variables.

Some have argued that failure to include a reversal phase in the changeover design leads to confounding of preference for the alternate condition with preference for stimulus change and conclude that, to avoid this problem, the

symmetrical design should always be used (e.g., Safarjan & D'Amato, 1978). This confounding does exist in the unidirectional procedure: Baseline responses made during the training phase produce no stimulus change, but responses made during the changeover phase do. At issue is whether this confounding is serious; that is, does it compromise the validity of findings gathered with the unidirectional procedure? The issue is important, for if a reversal phase is always necessary, then considerable published research based on the unidirectional procedure needs to be redone.

Furthermore, adding a reversal phase doubles the length of an experiment. In parametric studies this is likely to extend a study by months. It is therefore important to know whether the additional time, expense, complexity, and stress to the subjects imposed by the bidirectional procedure are necessary.

One way to resolve this issue is to determine whether a symmetrical procedure leads to results different from those already reported for the unidirectional procedure (e.g., Badia & Culbertson, 1972). Experiment 1 explored this question. Six subjects chose between schedules of signaled versus unsignaled shock in a two-lever operant chamber. During the training phase, the signaled and unsignaled schedules, identified by discriminative stimuli, alternated at 1-min intervals. During the changeover phase, the subjects could change from the signaled to the unsignaled component by pressing one lever and from the unsignaled to the signaled component by pressing the other lever. At issue was whether this symmetrical procedure and the unidirectional changeover procedure yield comparable data.

EXPERIMENT 1

METHOD

Subjects

Six experimentally naive female Sprague-Dawley rats (Holtzman Co.), 90 to 130 days old at the beginning of the experiment, served. They were housed in individual chambers and had free access to food and water between experimental sessions. A reversed 12-hr light/dark cycle was in effect in the colony room.

Apparatus

Subjects were trained and tested in 2 two-lever operant chambers measuring 22.9 cm

long by 23.5 cm wide by 24.1 cm high. The side and back walls of each chamber were aluminum and the front wall (door) was Plexiglas. The levers required 20 g (.196 N) to depress and were located on the right wall 4.4 cm above the floor. Offset of light from a 1.27-cm jeweled lamp above the right lever indicated the start of an experimental session and its onset indicated the end. A 2.54-cm white jeweled lamp above the left lever provided stimuli (light and darkness) correlated with the signaled and unsigned shock conditions.

The chamber floor consisted of twelve 6.5-mm stainless steel rods spaced 1.9 cm center to center and oriented parallel to the door. Scrambled shock (3.5 mA, .5 s) was generated by a BRS SGS-003 constant-current shocker-scrambler and was delivered to the grid floor, metal walls, and levers of the chamber. A Plexiglas false ceiling was installed 11.4 cm above the floor to minimize unauthorized avoidance of shock.

Preshock signals (1000 Hz, 92 dB [C], background 82 dB [C]) were delivered by a 7.6 cm 8-ohm speaker mounted on the ceiling of the chamber. The chamber was enclosed in a sound-attenuating box and was programmed via solid-state logic (BRS, Inc.).

Procedure

Subjects served in 6-hr sessions on alternate days. Shock was delivered independent of the subject's behavior on a variable-time 120-s (VT 120-s) constant-probability schedule (Fleshler & Hoffman, 1962) modified to accommodate a minimum intershock interval of 8 s. To minimize the effect of shock-elicited responding on changeover, responses on the changeover levers that occurred within 2.5 s following shock onset had no programmed consequences (changeover delay).

The experiment was conducted in two phases, training and changeover. Subjects remained in each phase until the percentage of time spent in the changeover condition stabilized within 10% across three successive sessions.

Training phase. During the training phase, a multiple schedule was in effect with discriminative stimuli identifying the signaled and unsigned shock schedules (illumination or nonillumination of the houselight) counterbalanced across subjects. Shocks scheduled during the signaled component were preceded by

a 5-s tone; those scheduled during the unsigned component were delivered without the tone. Signaled and unsigned shock components alternated at 1-min intervals, resulting in half of each session being spent in the signaled condition and half in the unsigned condition. Responses on the levers were recorded but had no programmed consequences. However, these responses served to provide a baseline for responding (i.e., time that would have been spent in the alternate condition, had the responses been effective).

Changeover phase. The changeover phase was presented following the training phase. During changeover, components of the multiple schedule alternated as in training except when affected by responses on the levers. Responding on the left lever when the unsigned component was present advanced the schedule to the beginning of the signaled component; responding on the right lever when the signaled component was present advanced the schedule to the beginning of the unsigned component. Additional responses on the right lever when the signaled component was present or on the left lever when the unsigned component was present had no consequences.

All subjects experienced the initial training and changeover phases and also a replication of this sequence.

RESULTS AND DISCUSSION

Figure 1 presents the percentage of time spent in the signaled condition, averaged across the final three sessions of each phase, for individual subjects. Unfilled bars indicate performances during training, and filled bars indicate performances during changeover. The correlated stimulus identifying the signaled condition was light for the three subjects whose data appear in the upper half of the figure and darkness for those whose data appear in the lower half.

Indifference between conditions is indicated by a score of 50%. During training, lever pressing had no effect on the conditions, but the time that would have been spent in each condition, had these responses been effective, was recorded and provides a baseline for responding. Any deviations from 50% during training may be attributed to random error (if unsystematic) or to response bias (if systematic). The data shown in Figure 1 reveal little of either as even the most extreme deviation

Fig. 1. Percentage of time spent in changeover to the signaled condition during training (unfilled bars) and changeover (filled bars) phases, averaged over the final three sessions, for individual subjects in the symmetrical procedure. A score of 50% denotes indifference.

(Subject BCO-11, first training phase) was less than 9% from the 50% point.

Preference was assessed during the changeover phases (filled bars). Although subjects could change to either condition at any time during changeover, five of the six subjects responded to remain in the signaled-shock condition from 79% (Subject BCO-13) to 96% (Subject BCO-2) of session time over the final three sessions of the initial changeover phase. This performance was not due to a bias for one lever appearing late in training, as the subjects returned to the 50% preference level in the immediately following training phase (second unfilled bars). Return to initial changeover levels during replication of the changeover phase (second filled bars) shows that preference for the signaled condition was stable and reliable. (Subject BCO-1 learned to avoid shock by rolling on her back and therefore did not complete the second changeover phase.)

One subject (BCO-14) remained indifferent to the conditions throughout testing. Response rates on the levers appear adequate to have allowed the subject to contact the changeover

contingencies and it is unclear why performance of this subject differed from that of the others.

Response patterns of those subjects demonstrating a preference were identical to those seen with the standard changeover procedure: When the signal component terminated, subjects immediately reinstated it—usually with a single response. In addition, strong preferences emerged whether the correlated stimulus identifying the signaled condition was light or darkness. These results replicate those previously reported using the standard changeover procedure (e.g., Abbott & Badia, 1979; Badia & Culbertson, 1972; Badia, Culbertson, & Lewis, 1971; Lewis & Gardner, 1977). They rule out stimulus change, photic reinforcement, and response-contingency asymmetry as alternative explanations for previous findings.

EXPERIMENT 2

Our second experiment relates to earlier research concerning subjects choosing a schedule of high density signaled shock over lower density unsignaled shock (Badia, Coker, & Harsh, 1973). In this study subjects were first trained and tested with equal-density signaled and unsignaled shock schedules. As expected, a strong preference emerged for the signaled schedule. Shock density of the signaled schedule was then gradually increased until subjects stopped responding for the signaled schedule. It was found that subjects continued responding until the density of signaled shock was up to three times the density of unsignaled shock. The latter was taken as a measure of strength of preference for signaled shock.

Others disagreed with this interpretation (Biederman & Furedy, 1976b) and argued that continued preference for the signaled condition, following increases in shock density, may have resulted from "response fixation." This fixation is said to occur when previously established responses are reflexively elicited by some mechanism which becomes increasingly effective with stronger or more frequent shock. Experiment 2 ruled out response fixation as an alternative explanation. Instead of gradually increasing shock density, we maintained the density of signaled shock at twice the density of unsignaled shock throughout training and testing.

METHOD

Subjects

Four experimentally naive female Sprague-Dawley (Holtzman Co.) rats served. Conditions of maintenance were the same as those of Experiment 1.

Apparatus

The apparatus was the same as that described in Experiment 1, except that a constant wattage shocker-scrambler (BRS Model SGS-001) was used. Shock was set at 75 mW and .5 s.

Procedure

Subjects were studied in 6-hr sessions every other day. Illumination and nonillumination of the chamber identified the two conditions and these were counterbalanced across subjects. In the signaled condition a 5-s tone (1000

Hz, 92 dB [C], background 82 dB [C]) preceded each shock. No signals were presented in the unsignaled condition.

Scrambled shocks were delivered independent of behavior on variable-time, constant-probability schedules (Fleshler & Hoffman, 1962) modified to accommodate an 8-s minimum intershock interval. Shocks were delivered on a VT 120-s schedule for the signaled condition and a VT 240-s schedule for the unsignaled condition. Responses occurring within 2 s following shock were ineffective (changeover delay), minimizing the possibility of shock-elicited changeover responding. Subjects remained in each phase until the stability criterion (three consecutive sessions within 10%) was met.

Training phase. In training, half of each session was spent in the signaled-shock condition and half in the unsignaled condition. Responses on the levers had no scheduled conse-

Fig. 2. Percentage of time spent in changeover during training (TR), changeover from unsignaled to signaled shock (CO-SIG), and changeover from signaled to unsignaled shock (CO-UN) by individual subjects during the final three sessions of each condition in Experiment 2. Density of signaled shock was twice that of unsignaled shock throughout.

quences but they were recorded along with the time that would have been spent in the signaled condition had they been effective (baseline).

Changeover from unsignaled to signaled shock. During the changeover phase, the unsignaled condition remained in effect in the absence of responding. However, a single response on either lever produced the signaled condition for 1 min (changeover period). Further responses on the levers during the changeover period were recorded but had no scheduled consequences.

Changeover from signaled to unsignaled shock. The procedure was identical to changeover from unsignaled to signaled shock except that signaled shock was made the imposed condition and unsignaled shock the alternate condition. Subjects were twice trained and tested for changeover from unsignaled to signaled shock. This procedure was then repeated for changeover from signaled to unsignaled shock.

RESULTS

The percentage of time spent in the changeover condition for each subject during the last three sessions of each phase is shown in Figure 2. During the initial (baseline) training phase (first panel), all four subjects responded at rates sufficient to spend less than 25% of session time in changeover. During the changeover phase (second panel), however, two subjects (D1 and D6) spent over 70% of session time in the signaled condition. Subject D4 made few responses during changeover and it was possible that it had simply failed to make sufficient contact with the changeover contingency. This animal was therefore trained and tested a second time (unfilled squares, first and second panels). On retesting, Subject D4 changed to the signaled condition at high rates. One subject (D6) failed to develop a preference for the signaled condition despite apparently adequate response rates.

All subjects were then retrained and tested again for changeover to the signaled condition. Response rates in training (third panel) were somewhat higher than on the previous occasion but remained well below those evidenced during changeover. Changeover to the signaled condition (fourth panel) replicated previous changeover results.

Subjects were then trained a third time (fifth panel) and given the opportunity to change

from the signaled to the unsignaled condition (sixth panel). Again, levels of changeover during training were low relative to previous changeover performances. However, changeover to unsignaled shock was suppressed relative to those training levels. This pattern was repeated in the subsequent replication (panels 7 and 8).

GENERAL DISCUSSION

Experiment 1 demonstrated that findings obtained from a symmetrical choice procedure are virtually identical to those obtained from the standard unidirectional changeover procedure. It can be concluded that results from the standard procedure are due neither to response bias nor to stimulus change, and that the procedural asymmetry inherent in the standard procedure does not compromise the results obtained. This finding is consistent with existing data (e.g., Badia, Harsh, & Coker, 1975; Lewis & Gardner, 1977; Safarjan & D'Amato, 1978). Badia et al. (1975) tested preference for fixed-time (FT) versus variable-time (VT) shock schedules using the changeover procedure and a reversal phase (i.e., bidirectional design). Subjects changed from FT to VT shock, but not vice versa, whether shocks in both schedules were signaled or unsignaled. As noted by Lewis and Gardner (1977), if changeover responding were due to stimulus change or response asymmetry, then subjects should have changed over under both options. Similar results were reported by Safarjan and D'Amato (1978), who also used the changeover procedure with a reversal phase.

Lewis and Gardner (1977) tested preference for signaled over unsignaled shock schedules using a bidirectional procedure similar to that of the present Experiment 1. Their procedure differed from that reported here in that responses changing the schedule from signaled to unsignaled shock and vice versa were programmed on the same lever. Two subjects with previous experience on the unidirectional changeover procedure rapidly demonstrated a strong preference for the signaled schedule but an additional four naive subjects did not. Lewis and Gardner (1977) concluded that preference for signaled over unsignaled shock could be demonstrated with a symmetrical procedure, but that the particular symmetri-

cal procedure they used appeared to be inferior to the changeover procedure.

Others have disputed this conclusion on grounds that only the subjects not previously exposed to the unidirectional changeover procedure provided a valid test of choice in the symmetrical procedure (Biederman & Furedy, 1979). However, the present findings do not support this argument. They show that naive subjects will demonstrate a strong preference for signaled- over unsignaled-shock schedules if the two contingencies (changing from unsignaled to signaled and vice versa) are arranged on different levers.

Experiment 2 demonstrated that subjects will change from low density unsignaled shock to high density signaled shock even when trained and tested throughout on unequal density schedules. Obviously prior experience with equal-density shock is not a necessary condition for preference. This finding rules out a "response-fixation" analysis of Badia, Coker, and Harsh's (1973) shock density findings. It also suggests that response fixation is an unlikely explanation for the finding that subjects prefer longer or stronger signaled shock over shorter or weaker unsignaled shock (Badia, Culbertson, & Harsh, 1973).

Other data support this conclusion. Parametric studies using the changeover procedure (e.g., Abbott & Badia, 1979; Badia, Harsh, Coker, & Abbott, 1976; Harsh & Badia, 1975, 1976; Safarjan & D'Amato, 1978) show that changeover responding varies systematically with schedule parameters such as signal length, shock intensity, and intershock interval. This should not be the case if changeover responding occurs simply because of response fixation. In addition, the response-fixation analysis predicts that subjects will change over in both directions when a reversal phase is used, but they do not (e.g., Harsh & Badia, 1975; Safarjan & D'Amato, 1978; for a fuller discussion of these issues see Badia & Harsh, 1977a, 1977b; Badia, Harsh, & Abbott, 1979; Harsh, 1978).

The results of Experiment 2 confirm those of Badia, Coker, and Harsh (1973) and again demonstrate the strength with which signaled-shock conditions are preferred over unsignaled ones. We have argued on the basis of converging lines of evidence that this preference is controlled by stimuli identifying periods of relative safety, which are available only in the signaled schedule (for recent reviews see Badia

et al., 1979; Fantino & Logan, 1979). However, recent evidence is beginning to reveal the importance of other factors that appear to modify the attractiveness of the signaled schedule in ways not predicted by the safety analysis as currently developed (e.g., Abbott & Badia, 1979; Badia, Abbott, & Schoen, 1983), and it now appears that a full understanding of the mechanisms underlying preference may require knowledge of the physiological effects of signaling aversive events. Toward this end, we have recently completed a review of this literature (Abbott, Badia, & Schoen, 1983).

Ultimately, experimental results are accepted or rejected by their "fit" with other experimental data and their replicability. The data produced by the changeover method provide a consistent view of preference for signaled shock that both supports and is supported by findings gathered with other methods.

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