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BEHAVIORAL CONTRAST AFTER ERRORLESS DISCRIMINATION LEARNING AS A FUNCTION OF NON-CONTINGENT SHOCK

by

James H. Kaye

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of the
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James Harper Kaye

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INTRODUCTION

The phenomenon now called behavioral contrast was first reported by Pavlov (1927). Pavlov, while studying salivary conditioning and discrimination learning, found that increases in salivation occurred during the presence of the positive conditioned stimuli when these stimuli were immediately preceded by stimuli associated with extinction. Pavlov termed this effect "positive induction."

Skinner (1938) demonstrated that similar changes in responding can result during operant discrimination training. Skinner observed changes in rate of responding to discriminative stimuli following discrimination training and termed the effect "contrast".

Reynolds (1961a), has referred to the phenomenon observed by Pavlov and Skinner as "behavioral contrast". Reynolds defined behavioral contrast as a change in the rate of responding during one procedurally constant component of a multiple schedule in a direction away from the rate of responding generated by a procedural manipulation during a second component. When the rate change is in the form of an increase in response rate the effect is called positive contrast. When the rate change is a decrease in response rate the effect is called negative contrast (Reynolds, 1961b).

A less frequently observed behavioral interaction is induction (Reynolds, 1961b). Induction refers to a rate change in one component of a multiple schedule which is in the same direction as a rate of responding obtained through the manipulation of another component of that multiple schedule. Positive induction refers to an increase in response rate in both components; negative induction refers to a decrease in response rate in both components. Because of the breadth of the subject area this review will be limited only to studies concerning behavioral contrast.

Various subjects, response topographies, and reinforcers have been employed in studies reporting behavioral contrast. Reynolds (1961a) studied pigeon key pecks reinforced by grain, O'Brien (1968) studied human button presses reinforced by money, Hitzing and Schaeffer (1968) studied rat lever presses reinforced by food pellets, and Williams (1965) investigated rat wheel running behavior using intracranial brain stimulation as the reinforcer.

Behavioral contrast has been studied using a variety of reinforcement schedules. Powell (1971) employed multiple (mult) schedules consisting of variable ratio (VR), variable interval (VI), and extinction (EXT) schedules. Wilkie (1973) used both multiple and concurrent (conc) schedules. Bloomfield (1967) employed fixed ratio (FR) schedules, and Brownstein (1969) obtained contrast using mult VI fixed interval (FI) schedules. Reynolds and Limpo (1968) utilized differential reinforcement of low rates of responding (DRL) while Reynolds (1961a) and Nevin (1968) employed differential reinforcement of other behavior (DRO).

There are several ways of assessing behavioral interactions. A between session analysis assesses changes in responding across sessions or experimental conditions. For example, mean rate of responding in component A prior to the manipulation of component B may be compared to mean rates of responding in component A after the manipulation of component B. Reynolds and Limpo (1968) employed a between session analysis when they assessed changes in rate of responding over sessions in both components of a two-ply multiple schedule when that schedule was changed from mult DRL 35 DRL 35 to mult DRL 35 DRL 35 (plus interresponse time clock). Reynolds (1961a) studied total responses per session for both components of two-ply multiple schedules prior to and after the manipulation of the stimulus conditions in one component.

In addition to the between session analysis, a between component analysis may also be used to assess changes in rate of responding between components during a session. Such analysis usually compares response rates during components A which follow similar components (A) with rates during components A which follow different components (B). Changes in response rates assessed through this technique are termed sequential interaction effects (Terrace, 1966a; O'Brien, 1968). Terrace (1966a) randomly presented reinforced and non-reinforced components to pigeons and observed that faster key pecking occurred during reinforced components when those components were preceded by non-reinforced components. O'Brien (1968) reported similar sequential contrast effects with human subjects.

A third analysis of interactions assesses rate changes within each component of the session as a function of the immediately preceeding or following component(s). Changes in response rates assessed by this method have been referred to as transient interaction effects (Nevin and Shettleworth, 1966). Nevin and Shettleworth alternated each three minute component of a mult VI 2 VI 6 and found that pigeons responded faster during the first 30 seconds of VI 2 components and slower during the first 30 seconds of VI 6 components. They also reported that responding increased to a stable level after the first 30 seconds of VI 6. The change in responding from the initial low rate in the VI 6 to the higher rate observed later in the same component is an example of negative transient contrast; the change from the initial high rate in the VI 2 to the lower rate observed later in the same component is an example of positive transient contrast (Nevin and Shettleworth, 1966, p. 308).

A variety of conditions have been shown to be effective in producing behavioral contrast. Procedures which change the absolute frequency of reinforcement in one component of a multiple schedule have been successful in producing contrast (Reynolds, 1961a, 1961b, 1961c, 1963; Reynolds and Catania, 1961). When Reynolds (1961a) decreased the absolute frequency of reinforcement in the second component of a mult VI 3 VI 3 by changing to mult VI 3 EXT he created a condition in which the first component produced relatively more reinforcements per unit time than the second component. Reynolds reported reliable positive contrast effects as a result of this procedure.

It is not necessary to change the reinforcement schedule of one component to extinction (zero reinforcement) in order to produce contrast effects; most manipulations that change the absolute frequency of reinforcement in one component are equally effective (Reynolds, 1961a). Thus a change from mult VI 2 VI 2 to mult VI 2 VI 6 would likely produce a positive contrast effect in the constant component. Similarly, interspersing occasional periods of time out (TO) from positive reinforcement during one component enhances responding in the constant component. Any manipulation of absolute frequency of reinforcement of one component typically alters the relative frequency of reinforcement in the constant component, while the relative response rate in the constant component is an increasing monotonic function of the relative rate of reinforcement earned in that component (Nevin, 1968).

Although the relative frequency of reinforcement may be manipulated by changing ratio requirements in one component of a multiple schedule, it may be more advantageous to manipulate interval schedules. Marked variations in the response rate can substantially alter the absolute rate of reinforcement for a given ratio schedule, and thus interaction effects resulting from changes in the absolute frequency of reinforcement in the manipulated component may be confounded with changes in the relative and absolute reinforcement frequency in the constant component. Interval schedules, however, provide a relatively constant absolute frequency of reinforcement over a wide range of response rates.

Punishment of responding in one component has also been shown to be effective in producing behavioral contrast. Brethower and Reynolds (1962) punished each response during one component of a mult VI 3 VI 3 schedule of reinforcement which resulted in a positive contrast effect. They also reported that increments in shock values enhanced the contrast effect. Terrace (1968) and Rachlin (1966) have both reported similar results using a mult VI 1 VI 1 with a punishment contingency superimposed in one component.

Successive errorful discrimination training procedures often produce contrast effects (Terrace, 1963a). In this procedure responding is initially reinforced in the presence of one stimulus (S+) for several reinforcements, then a second stimulus is added during which no reinforcement is programmed (S-). The two components are then usually presented alternately in random succession. Errorless training employs a fading procedure whereby stimuli associated with non-reinforcement are gradually introduced in a manner which produces little or no unreinforced responding in the presence of those stimuli. Terrace (1963a, 1963b, 1963c) has reported that following errorless discrimination training, extinction conditions fail to produce contrast effects.

Reynolds and Limpo (1968) employed stimulus control techniques to reduce the rate of response in one component of a mult DRL 35 DRL 35 schedule of reinforcement. An interresponse time (IRT) clock consisting of cue lights indicating each successive five second IRT was added to one component, resulting in a decrease in responding and subsequent increase in absolute frequency of reinforcement in that component. A positive contrast effect was obtained in the constant component even though the increase in responding produced a decrease in the frequency of reinforcement in that component.

Another condition which appears to produce contrast effects is manipulation of the magnitude of reinforcement.

Although Shettleworth and Nevin (1965) did not find that variations in hopper time consistently produced positive or negative contrast effects, Keesey and Kling (1961) have obtained transient contrast effects when the magnitude of reinforcement in the next component was signaled by a probe stimulus.

The temporal or spatial proximity of discriminative stimuli seems to aid in the production of behavioral contrast. Catania and Gill (1964) reported an increase in response rate (positive contrast) when S+ was closer in space to S- than when it was closer in space to another S+. Pliskoff (1961, 1963) found that when a pre-stimulus change during the later part of one component of a multiple schedule indicated a shift to a lower frequency of reinforcement in the next component, an increase in responding was observed during the pre-stimulus change. When the pre-stimulus change indicated an increase in reinforcement frequency in the next component the response rate during the pre-stimulus change decreased.

Three major determinants of behavioral contrast have been postulated. Reynolds (1961c) suggests that the necessary condition for the production of behavioral contrast is a change in the absolute frequency of reinforcement in one component of a multiple schedule. Reynolds concluded this after observing that responding in the constant VI component of a multiple schedule was enhanced when the second VI component was changed to either time out (TO) or extinction (EXT). This procedure, however, effected not only a decrease in the number of reinforcements in the changed component, but also a decrease in the response rate in that component. Reynolds then attempted to separate the effects of non-responding from the effects of non-reinforcement by changing TO or EXT components to a schedule employing a differential reinforcement of other behavior (DRO) procedure. This procedure produced low rates of responding and high frequency of reinforcement in the changed component while eliminating contrast effects in the constant component.

Terrace (1966a, 1968) disagreed with Reynolds and suggested that a change in response rate in one component was the necessary condition for the production of contrast in a second component. Both Terrace (1968) and Brethower and Reynolds (1962) have shown that the addition of a punishment contingency in one component of a mult VI VI schedule produces a decrease in responding in that component concomitant with an increase in responding in the constant component (positive contrast). This effect occurs even when the reinforcement frequencies associated with both components are held constant. Terrace (1968) argued that the change in responding in the manipulated component was functional in producing contrast since the relative frequency of reinforcement remained the same for both components. Additional support for Terrace's argument is presented by Reynolds and Limpo (1968) who demonstrated that a reduction in response rate in one DRL component while maintaining reinforcement in that component resulted in an increase in responding in the constant DRL component. Brownstein (1969) has reported similar data with multiple interval schedules (VI and FI) after cuing the availability of reinforcement in one component.

According to the frequency of reinforcement theory, procedures such as those employed by Brethower and Reynolds (1962) and Terrace (1968) should not produce contrast since no manipulation of the reinforcement frequency is made. Thus Reynolds' theory fails to account for the contrast effects produced in these studies.

However, Terrace's theory cannot account for the contrast effects reported by Nevin and Shettleworth (1966). Positive transient contrast was obtained in the VI 5 component of the multiple schedule subsequent to the replacement of a VI 1 DRO component with an EXT component, even though responding in the VI 1 DRO and EXT components was low (less than one response per component cycle) throughout the experiment.

There are further problems with both theories. The frequency-of-reinforcement theory requires the manipulation of the absolute frequency of reinforcement in one component and assesses the resulting response rate changes in the constant component. However, changes in the absolute frequency of reinforcement in one component typically effects concomitant changes in rate of responding in that component. Since two variables (response rate and reinforcement frequency) are simultaneously manipulated, it becomes difficult to specify which of the two variables is functional in producing any resulting behavioral effects.

A similar confounding of independent variables may occur in most research which argues for the relative-rate-of-responding theory. Studies which purport to manipulate only the rate of responding by employing stimulus control, punishment, and aversive stimulation procedures may confound the effects of rate changes with changes in the relative aversiveness of those procedures. Thus while Terrace (1968) held the relative frequency of reinforcement constant while supposedly changing only the rate of response in one component, he also introduced an aversive event (shocks) into the stimulus complex of the manipulated component.

The failure of both the rate change and relative reinforcement theories to fully account for the development of contrast suggests that some major determinant of behavioral contrast remains to be identified. Bloomfield (1969) has observed that there are in all cases of positive contrast some "worsening" of conditions in the changed component. He suggests a third theory that a change for the worse in one component is a necessary and sufficient condition for the production of contrast. It is not clear, however, how Bloomfield would account for negative contrast obtained when the frequency of reinforcement in one component of a multiple schedule is substantially increased. It would appear that an appropriate analysis would include the notion of changes in contrasted conditions of reinforcement between components rather than qualitative changes within a single component.

Hitzing (1969) suggests that changes in the relative reinforcing or aversive properties of a component are crucial to the production of behavioral contrast. Thus a positive contrast effect would be expected as a result of the presentation of response-contingent shocks in one component of a mult VI VI (Terrace, 1968) since shock presentations would both decrease the absolute reinforcing properties of the punished component and increase the relative reinforcing properties of the unpunished component.

The unusual contrast effect reported by Reynolds and Limpo (1968) might also be explained by appealing to the notion of changes in the relative reinforcing or aversive properties of multiple schedule components. In their study, a mult DRL 35 DRL 35 was changed to a mult DRL 35 DRL 35 (plus IRT clock). The clock consisted of eight cue lights that lighted sequentially after each successive five second IRT. Any responses occurring prior to the operation of the eighth light recycled the clock and restarted the reinforcement timing operation. This procedure resulted in (1) a decrease in responding during the IRT clock component with a subsequent increase in rate of reinforcement and (2) an increase in responding in the constant component with a subsequent decrease in reinforcement rate. The result described in (1) might be predicted since the first seven lights function as successive periods of S- and the eighth light functions as a signal for reinforcement availability. It is reasonable to expect that the pigeon will shortly learn to peck in the presence of the eighth light (S+) and not to peck in the presence of any other light (S-). This simple discrimination training should produce consistent low rates of responding and provide a nearly maximum frequency of reinforcement (limited only by the minimum IRT criterion for reinforcement). An explanation of the results described in (2), the increase in responding in the constant component and subsequent decrease in reinforcement per unit time in that component, requires a basic understanding of DRL schedules. A DRL _t_ ensures that the subject will only be reinforced for responding after _t_ seconds have elapsed between responses or reinforcements. Thus the organism is required to discriminate the reinforced IRT from all shorter IRTs. Bloomfield (1969, p. 221) suggests that such discriminations are relatively difficult for pigeons to make and further suggests that, other things remaining equal, a pigeon will prefer a schedule which does not make such demands on its timing capacities. This being the case, it would seem that a change from DRL 35 to DRL 35 plus IRT clock would represent a change from an aversive condition to a substantially better condition, since fewer demands are made on the pigeon's timing capacities in the latter schedule.

The relative aversive properties of the constant component DRL are substantially increased as the changed component's aversive properties decrease. It may be said that conditions in the changed component have become both absolutely and relatively better, since the subject performs a simpler discrimination and receives significantly more reinforcements then he did either previously in that component, or currently in the unchanged component.

It is reasonable to assume that the increase in relative aversiveness of the constant component might result in the breakdown of time-based discriminations. Hearst (1965) has shown that discrimination performance can be seriously disrupted by the delivery of unavoidable shocks, with or without warning, in either S+ or S-. Hearst suggests that the results indicate that aversive stimulation may have significant side effects on well-learned appetitive discriminations. Thus an increase in the relative aversiveness of the constant DRL component might be functional in breaking down IRT discriminations, resulting in an increase in short IRTs. The resulting increase in unreinforced responding and subsequent decrease of reinforcements per unit time further increases the aversiveness of the constant component.

The theory suggested by Hitzing (1969), if valid, would clearly offer an explanation of contrast with broader generality than those previously offered. One powerful test of the theory would involve increasing the aversiveness of one component of a multiple schedule without changing the response rate or absolute frequency of reinforcement in that component.

Almost ideal conditions for such a test were supplied by Grusec (1968) in his study of peak shift as a function of discrimination training procedures and non-contingent shock. A short review of the peak shift and its relationship to behavioral contrast seems in order before a discussion of this study is undertaken.

The peak shift was first studied systematically by Hanson (1959). Hanson found that after a pigeon was reinforced for responding to one stimulus from one dimension and not another, a post-discrimination training generalization test revealed that responding had substantially increased to the original training stimulus (contrast) but that the peak of the resulting generalization gradient had shifted away from the original S-.

Since behavioral contrast and peak shift are both possible by-products of successive discrimination training

(Bloomfield, 1969, p. 216), several researchers have attempted a systematic analysis of both phenomena using basically the same experimental paradigm: successive discrimination training and post-discrimination generalization tests (Guttman, 1959; Terrace, 1964; Terrace, 1966; Terrace, 1968). Terrace (1966) observed that training conditions which produce contrast also produce peak shift and that training conditions which do not produce contrast also fail to produce peak shift. Terrace subsequently argued that both behavioral contrast and peak shift have a common source, and that the analysis of the determinants of one would likely identify the determinants of the other.

Grusec (1968) used errorless discrimination training procedures to train one group of pigeons to discriminate between two stimuli of different wavelengths and used errorful training procedures to train another group of pigeons to make a similar discrimination. As predicted by Terrace (1968), positive contrast effects and peak shift away from S- were obtained in the errorful group but not in the errorless group. Grusec then tested Terraces' notion that peak shift occurs because S- becomes aversive, by programming free shocks during the S- (extinction component). Subsequent generalization tests showed a large peak shift for the errorless group and a larger peak shift for the errorful group than had been obtained before. Unfortunately, free shocks resulted in enotional behaviors, general suppression, and overall response irregularities which obscured possible contrast effects.

The results of the Grusec study are supportive of a theory of contrast based on the change of the relative reinforcing properties of schedule components. The contrast effects observed during successive discrimination training with the errorful procedure were to be expected since responding in the presence of S- went unreinforced and thus increased the aversive properties of that component while enhancing the relative reinforcing value of the S+ component. The peak shift obtained from this group was similarly expected. Since the errorless group emitted few unreinforced responses to S-, that component did not take on the usual aversive properties and hence no change in the relative aversive or reinforcing component properties occurred. Since S- took on no additional aversive properties, no peak shift was expected. Noncontingent shocks in the S- component then constituted an increase in the aversive properties of that component. Both contrast effects and peak shift would then be expected for both errorful and errorless groups. Since Grusec was primarily interested in the peak shift, his experimental design and procedures were tailored to the investigation of that phenomenon rather than behavioral contrast. Thus the sudden introduction of optimal shock values, while providing the conditions necessary for peak shift, obviated any meansurement of possible contrast effects.

The present study attempts to overcome some of the problems encountered by Grusec in his measurement of post-shock contrast effects, and attempts to (a) replicate some of the findings of Terrace and Grusec, (b) demonstrate contrast effects resulting from the increased aversiveness of one component of a multiple schedule without altering the response rate or relative frequency of reinforcement in that component, (c) offer additional support for a theory of contrast based on the alteration of reinforcing or aversive properties of components of multiple schedules.

METHOD

Subject

Four adult White Carneaux pigeons, all experimentally naive, were maintained within 15 g of 80% of their free-feeding weight. All birds were fed in their home cages, if required, between 30 minutes and 60 minutes after experimental sessions. All birds had free access to water and grit while in their home cages.

Apparatus

The experimental work space was a two-key operant chamber for pigeons, with the left key inoperative throughout the experiment. The side-loading chamber measured 14" (35.9 cm) high, 12" (30.8 cm) long, and 16" (41 cm) deep, and was contained within a larger shell. A Lehigh Valley grain hopper provided mixed grain through an aperture on the 15" (41 cm) right wall centered 5" (12.8 cm) above the chamber floor and midway between the front and back walls. Lehigh Valley translucent response keys, requiring an operating force of 25 g, were placed behind 1.0" (2.6 cm) holes centered 3" (7.7 cm) left and right of the hopper aperture and 10" (25.6 cm) above the chamber floor. The right key was transilluminated red during S+ by two miniature lamps covered by red translucent caps and enclosed in a metal light-sealed box directly behind the key. A feedback relay was mounted between the chamber and the shell and provided an audible click for each response to the lighted key. The left inoperative key was never lighted and responses to it did not produce feedback clicks. A .125" (.32 cm) thick frosted glass ceiling 12" (30.8 cm) by 16" (41 cm) was situated 14" (35.9 cm) above the chamber floor, and concealed the chamber roof to which was mounted a small houselight, a commutator through which shocks were delivered, and four small lamps located in each corner. A small hole in the center of the glass ceiling allowed passage of a 9.75" (25 cm) two-conductor stranded wire from the commutator to a small male two-prong AC plug. The male plug mated with a female plug secured to a harness worn by each bird. The harness was similar to that described by Azrin (1959), except that it was constructed of heavy vinyl with knit backing and was fitted to the bird with Velcro straps placed around each wing root (Kaye, 1973). Leading from the female AC plug were two 22 gauge wires each of which terminated at .025" (.064 cm) stainless steel electrodes. Each electrode was approximately 2" (5.1 cm) in length and was implanted around the distal end of each pubis bone in the manner described by Azrin (1959). Short 60 Hz AC shocks were administered through a 10 k ohms resistor in series with each bird. Shock voltages were controlled by the selection of various capacitors which could alter the length of operation of the shock output relay. Operation of the shock output relay was determined by a tape programmer. All VI intervals determining reinforcement or shock were based on the formula provided by Fleshler-Hoffman (1962). All contingencies and consequences were programmed via electro-mechanical equipment housed in an adjoining room. Gerbrands cumulative recorders, Esterline-Angus event recorders, and digital counters recorded data. A Grason-Stadler noise generator provided white noise to the experimental room and an exhaust fan mounted on the exterior shell provided both additional masking noise and ventilation whenever the shell was closed. A 12" (30.8 cm) square glass window in the shell door was used to view subjects and was covered with heavy black paper when observation was not required.

During hopper training, shaping, and errorless discrimination training, a small control box operated by the experimenter remotely provided reinforcement, lengthened S-, and controlled through a potentiometer the intensity of the four corner lamps. In addition, a small low intensity blue lamp attached to the box lighted during time out and was observable to the experimenter but not the bird.

Procedure

Following initial hopper training, all birds were shaped to peck the right key when it was lighted red while a single house light was on. Reinforcement was provided by 3 sec access to mixed grain illuminated by a small lamp in the aperture. During reinforcement the key light and house light were extinguished. Responding was maintained on a VI 15-sec reinforcement schedule by the second session for bird B3, third session for A2, and fourth session for A3 and B5. The first phase (Phase I) of early-progressive errorless discrimination training (Terrace, 1966) was begun and completed during the following session for A2, B3, and B5. The S+ component consisted of a 30-sec presentation of red key light and single house light during which responding was reinforced on a VI 15 sec schedule. Following this period was a 2.5-sec blackout during which (1) all chamber lights were extinguished (2) responding was not reinforced and (3) responding did not operate the feedback relay. The S- component immediately followed the blackout period, and initially consisted of a 1.0-sec interval of EXT for B3 and B5, and a 2.0-sec interval of EXT for A2. Although terminal S- stimulus conditions consisted of four bright corner lights and an unlighted response key, during Phase I all lights were extinguished during S- in order to decrease the probability of responding. Any responding, i.e., errors, during S- did not operate the feedback relay and resulted in 30 sec of time out (TO). During TO the chamber remained unlighted and further responding also failed to operate the feedback relay. In addition, each TO response reset the timer that timed the TO period. Another S- period of a length equal to the previous S- period immediately followed TO offset. This TO contingency and the stimulus conditions correlated with TO were maintained during all S- components throughout errorless discrimination training. Another 2.5 sec blackout separated the end of S- and the beginning of S+. Although the length of S+ was held constant at 30 sec throughout errorless training, each successive errorless S- period was lengthened by one to three seconds until a S- period of 30 sec was obtained. Approximately five cycles of 30 sec of S+, 2.5 sec of blackout, 30 sec of S-, 2.5 sec of blackout, were then programmed, followed by the termination of the session.

The second and third phases (Phase II and III) of errorless discrimination training were begun and completed the following session, and consisted of two fading segments. During Phase II, the schedule cycle was 30 sec of VI 15 (S+), 2.5 sec of blackout, 2 sec of EXT (S-), 2.5 sec of blackout. Across approximately ten successive S- periods the four corner lamps were simultaneously and gradually lighted and increased in intensity to full brightness. The response key(s) remained unlighted in order to decrease the likelihood of responding, and errors continued to produce TO. After full brightness in S- had been achieved, Phase III was begun. The length of each successive S- was gradually increased in the same manner as during Phase I, except the four corner lamps were at full intensity. This second segment was completed when full 30 sec intervals of S+ and S- were cycled ten times. The session was then terminated, and errorless discrimination training was essentially completed. The TO contingency for errors was no longer in effect for subsequent sessions.

Bird A3 began and completed Phase I of errorless training on session 12 and began and completed Phases II and III on session 13. The same procedure was employed as described above, except that a VI 30-sec reinforcement schedule was used.

The reinforcement schedule and component durations were gradually altered between and within sessions until each bird was maintained on a mult VI 1 min EXT schedule based on the following cycle: 2 minutes of VI 1 min (S+), 2.5 sec of blackout, 1 minute of EXT (S-), 2.5 sec of blackout. This cycle was established by session nine for birds A2 and B3, session 13 for B5, and session 17 for A3. Each session began with a S+ component and consisted of 31 S+ components and 30 S- components. A 5 min blackout was employed immediately prior to the start of each session and immediately following each session. One session was run daily, approximately seven evenings per week.

Approximately one hour after session 15 birds A2 and B3 were implanted with electrodes. Bird A3 was similarly implanted following session 107. Bird B5 was implanted prior to hopper training. All birds were fitted with shock harnesses prior to hopper training, and wore them at all times throughout the study. Implanted birds were plugged into the shock delivery system approximately five minutes before each session.

Following implantation and response stabilization in S+, non-contingent and unavoidable 50 msec presentations of 30 v shock were programmed on a variable time (VT) 30 sec schedule (VT 30) during S- to bird A2 beginning on session 28, B5 beginning on session 40, and A3 beginning on session 202. Beginning on session 32 bird B3 was similarly presented with 22 msec 30 v shocks. In all cases shock intensity was gradually increased in S- by slowly increasing voltage from 0 v to 30 v over approximately 20 shock presentations. The number of shock presentations in S- for all birds ranged from 44 to 54 per session with a mean of 48.2 per session (See Table 1).

Shock was terminated to A2 on session 65, but was reinstated at full value (30 v) on session 75. During session 82 the shock voltage presented increased gradually across the first 10 shock presentations to 60 v, and was similarly increased to 90 v during session 90 and 120 v during session 97. A shock commutator failure during sessions 113 and 114 provided an adventitious opportunity to supply a non-shock probe. The non-shock probe allowed a partial assessment of the effects of S-shock on S+ responding. The 120-v shock was resumed on session 115, with the shock gradually increasing to 150 v during session 126. Shock was removed beginning on session 163.

TABLE 1

Number of sessions in which shock occurred in S-, total of shocks in S-, mean number of shocks per session, and the range of shock frequencies per session for each bird.

Bird	Shock Sessions	Total Shocks	Mean Shocks per Session	Range
A2	125	6072	48.6	54-44
A3	90	4358	48.4	54-44
B3	59	2823	47.9	54-44
B5	81	3877	47.9	54-44

The shock presented to B3 was discontinued after session 50 and was reinstated at full value (30 v) on session 99. Shock was gradually increased across the first 10 shock presentations in session 117 to 60 v, and was terminated after session 139. During sessions 156, 157, and 158 each response in S+ produced a 22-msec 30 v shock in order to determine whether the shock could function as a punisher for B3. Responding during S+ continued to earn reinforcement on a VI 1 min schedule. Shock was terminated on session 159.

Shocks presented to B5 were gradually increased in intensity over the first 10 shocks during session 46 to 60 v, and were similarly increased to 90 v on session 53. Shocks were discontinued on session 75 and were reinstated at full value (90 v) on session 117. Shock voltage again was gradually increased during session 126 to 120 v, and 150 v during session 141. Shock was discontinued on session 164.

Shocks delivered to A3 were increased in the same manner as for other birds to 60 v during session 212, and were discontinued following session 225. Shocks were reinstated at full value (60 v) on session 232, and were gradually increased during session 239 to 90 v, session 249 to 120 v, and session 255 to 150 v. Shock was discontinued on session 280, and was reinstated at 30 v on session 306. The voltage was increased abruptly to 150 v at the beginning of session 308, and shocks were terminated on session 310.

Data collection consisted of daily tabulation of total S+ responses, S- errors, blackout responding, and number of reinforcements and shocks. In addition, total S+ responding was separated into five 24 sec bins allowing the inspection of response distribution throughout the 2 min S+ component.

RESULTS

Table 2 summarizes the data obtained during errorless discrimination training. Birds A2 and B5 each made one error, and A2 responded six times while in TO. The other birds made no errors. All birds were considered errorless according to the criteria provided by Terrace (1966).

Table 3 presents a summary of all S- responding for each bird during the entire experiment. The table displays low error counts for all birds considering the experiment length. Errors as a percentage of total responding varied from .0033% for A3 to .0184% for B3. Inspection of Esterline-Angus charts revealed that most errors occurred at the beginning of S- and were the result of "over-runs", that is, responding that carried through the blackout (which separated the components) and into S-.

Figures 1-4 portray S+ responding during the last nine sessions of the first baseline period (bl) and all subsequent experimental conditions. Since S- responding was either non-existent or at extremely low levels that would be unreadable on the graph, S- responses were not plotted.

Mean responding for bird A2 (Figure 1) during bl

TABLE 2

Total responses during S+, total reinforcements, total responses during blackout, total responses in S-(errors), total responses in time out for each bird during errorless discrimination training.

Bird	Errorless Training Phase	Total Responses During S+	Total Reinforcement	Total Responses In Blackout	Total Errors	Total Responses In Time Out
A2	Phase I	621	47	3	1	6
	Phases II and III	904	61	10	0	---
A3	Phase I	2422	66	26	0	---
	Phases II and III	2863	30	36	0	---
B3	Phase I	1044	66	13	0	---
	Phases II and III	1055	74	21	0	---
B5	Phase I	566	53	0	0	---
	Phases II and III	794	56	0	1	0

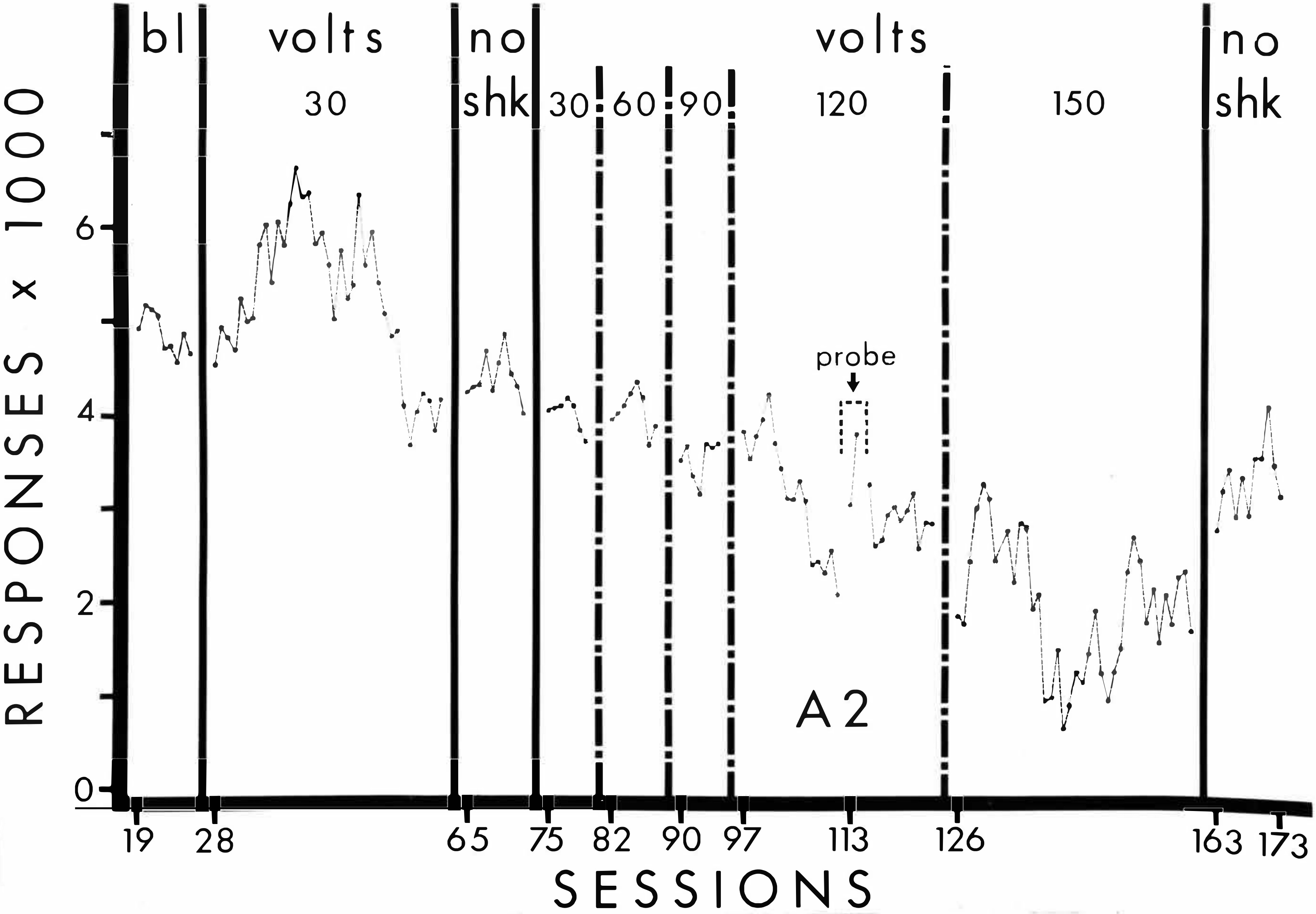
TABLE 3

Total errors, total sessions, total sessions in which errors occurred, range of error frequencies per session, mean errors per session for all sessions, mean errors per session for total errorful sessions for all birds throughout the experiment.

Bird	Total Errors (S- Responses)	Total Sessions	Total Sessions With Errors	ERRORS PER SESSION	
				Range	Mean For Errorful Sessions
A2	150	173	62	0-12	2.42
A3	55	327	37	0-5	1.49
B3	221	173	70	0-26	3.16
B5	100	187	47	0-17	2.13

FIGURE LEGEND

Figure 1: Thousands of responses over sessions for Bird A2. Baseline data appear under "bl". The numbers under "volts" indicate the shock voltage level present during S-. Shock is abbreviated "shk".

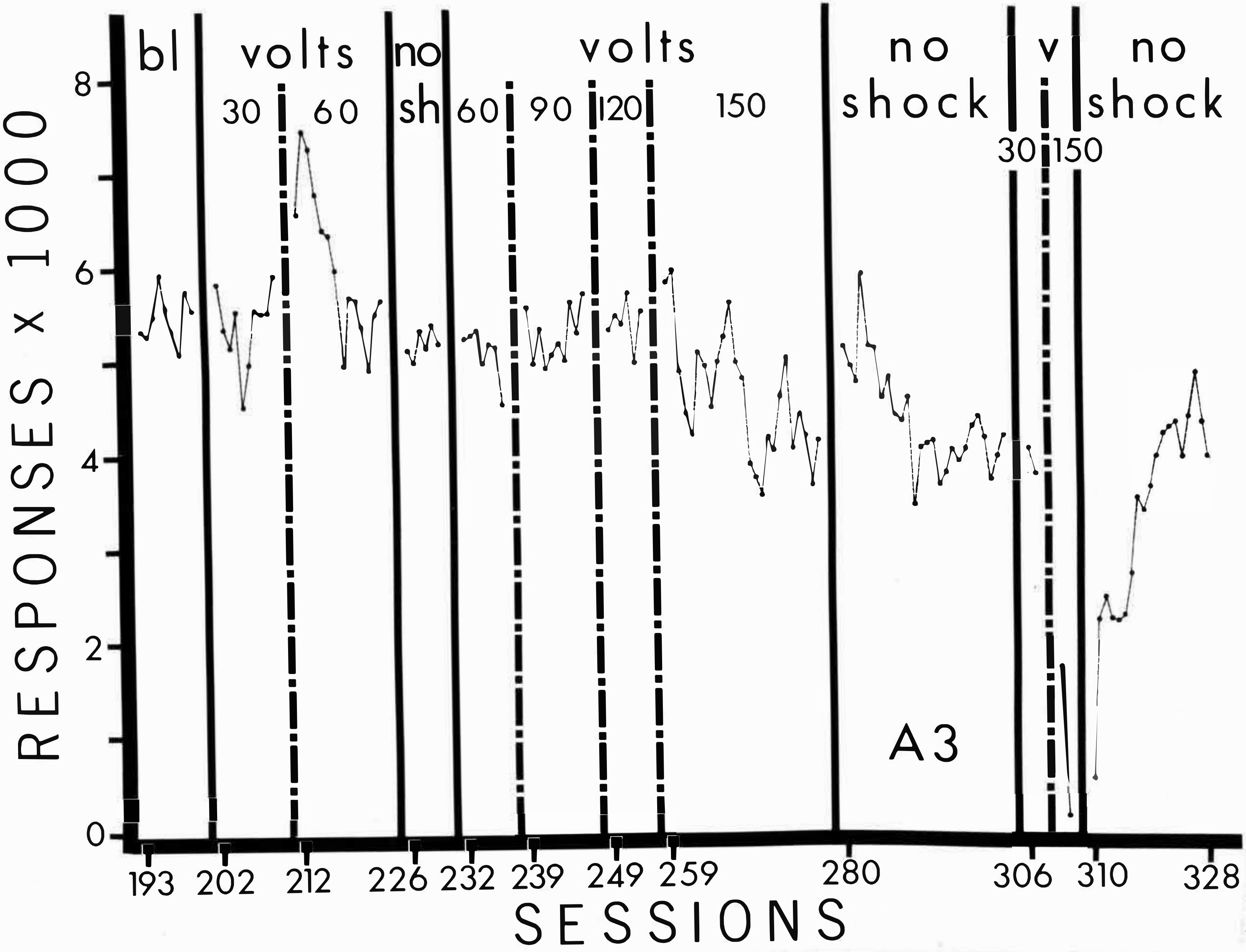

bl
volts
30
no
shk
30
60
90
volts
120
150
no
shk
probe
A2
RESPONSES x 1000
0
2
4
6
19
28
65
75
82
90
97
113
126
163
173
SESSIONS

was 4866. Following the introduction of shock in S- during session 28 responding increased and was asymptotic at 6658 (session 41). This positive contrast effect was not maintained as responding dropped to a mean of 4037 for the last seven sessions of that manipulation. During the subsequent ten sessions of no shock A2 produced a mean of 4410 responses. Reintroduction of shock during S- on session 75 failed to produce any pronounced effect on S+ response frequencies. No change in responding was apparent even during the subsequent 60 v stage. The 90 v shock presentations seemingly suppressed responding from the 60 v mean of 4060 responses to the 90 v mean of 3537 responses. The further increase in shock to 120 v during session 97 produced an increase in responding during the first few sessions, but responding deteriorated steadily from session 102 to session 112. The subsequent two-session probe of no shock reversed the trend and suggested that shock during S- was suppressing S+ responding. The first two sessions of 150 v shock (sessions 126 and 127) showed a marked decrease in responding. Further exposure to 150 v shock decreased responding to its lowest session level (626 responses). Responding increased to a mean of 1945 responses during the last eight sessions of 150 v. The subsequent no shock phase resulted in an immediate increase in responding to a mean of 3323 responses for the last eleven sessions.

Bird A3 averaged 5493 responses during bl (Figure 2)

FIGURE LEGEND

Figure 2: Thousands of responses over sessions for bird A3. Baseline data appear under "bl". The numbers under "volts" or "v" indicate the shock voltage level present during S-. Shock is abbreviated "sh".

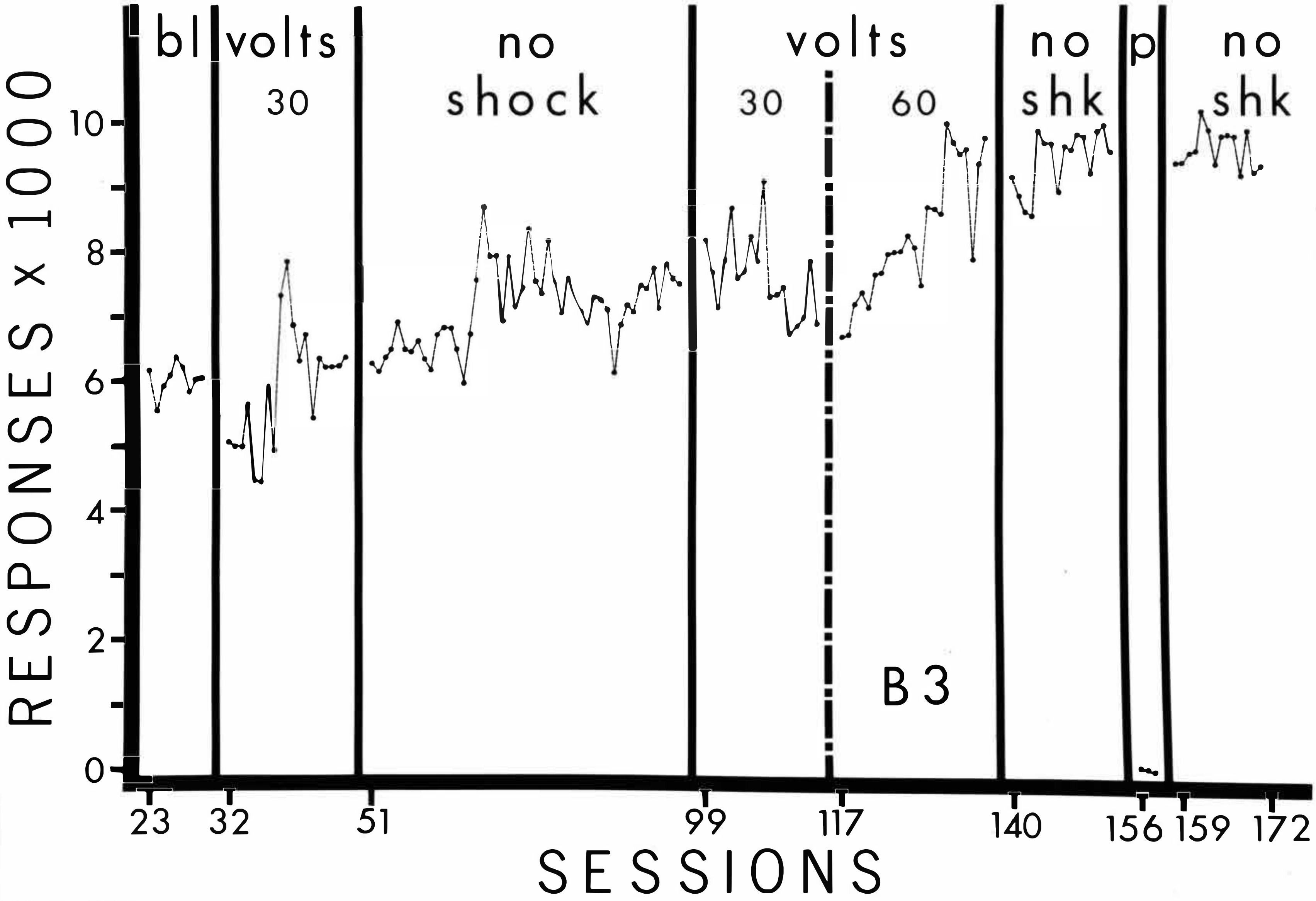

bl
volts
30
60
no
sh
60
90
120
150
volts
no
shock
v
30
150
no
shock
A3
RESPONSES x 1000
0
2
4
6
8
193
202
212
226
232
239
249
259
280
306
310
328
SESSIONS

but produced slightly fewer responses during the following 30 v shock during S-, averaging 5404 responses. However the introduction of 60 v shock resulted in an immediate positive contrast effect which was asymptotic at 7446 responses and which averaged 6889 responses for the first five 60 v sessions. The contrast effect was not maintained, and responding diminished to a mean of 5412 during the last five sessions of that manipulation. The cessation of shock beginning on session 226 resulted in a slight decrease in mean responding to 5185. Although the reintroduction of 60 v on session 232 failed to replicate the contrast effect, the subsequent presentation of 90 v shock produced a slight response facilitation averaging 5242. Increasing voltage to 120 v produced little change, although the introduction of 150 v in session 255 and 256 resulted in the most responding obtained since the initial 60 v contrast effect. Responding soon diminished to a mean of 4350 for the last nine sessions of that phase. The return to a no shock condition on session 280 resulted in 5136 mean responses during sessions 280-284. Responding decreased to a steady-state mean of 4059 during the last nine days of that phase. The introduction of 30 v shock on session 306 had little effect, but the abrupt shift to 150 v on session 308 demonstrated dramatically the suppressive effects of high voltage shock. Responding decreased to 1706 during session 308 and fell to 107 responses during session 309. The final no shock phase restored responding to a mean of 4287 during the final five sessions.

Bird B3 (Figure 3) averaged 6033 responses during bl. The introduction of 30 v shocks in S- produced a response decrement averaging 5044 responses for the first five shock sessions. Responding subsequently increased rapidly to an asymptote of 7846 responses (positive contrast). Contrast was again not maintained and the last five sessions produced an average of 6297 responses. The cessation of shock beginning on session 51 had no systematic effect on total response frequencies. An unexplained increase in session responses occurred later in the no shock phase; the last seven steady-state sessions averaged 7517 responses. The S- 30 v shocks reintroduced on session 99 produced more variability in responding, and increased the mean number of responses during the first five sessions of that phase to 7902 responses. The effect was temporary, and responding decreased toward the end of that phase. However, the introduction of 60 v shock produced a steady upward trend which was asymptotic at 9963 responses on session 133. This positive contrast effect averaged 9381 responses over the last five sessions of 60 v shock. This increase in responding was maintained through the subsequent no shock phase, although during the first four no shock sessions B3 showed a response averaging 8778 responses per session. The FR 1

FIGURE LEGEND

Figure 3: Thousands of responses over sessions for bird B3. Baseline data appear under "bl". The numbers under "volts" indicate the shock voltage level present during S-. Shock is abbreviated "shk". The 30 v punishment contingency in S+ during sessions 156, 157, and 158 is represented by "p".

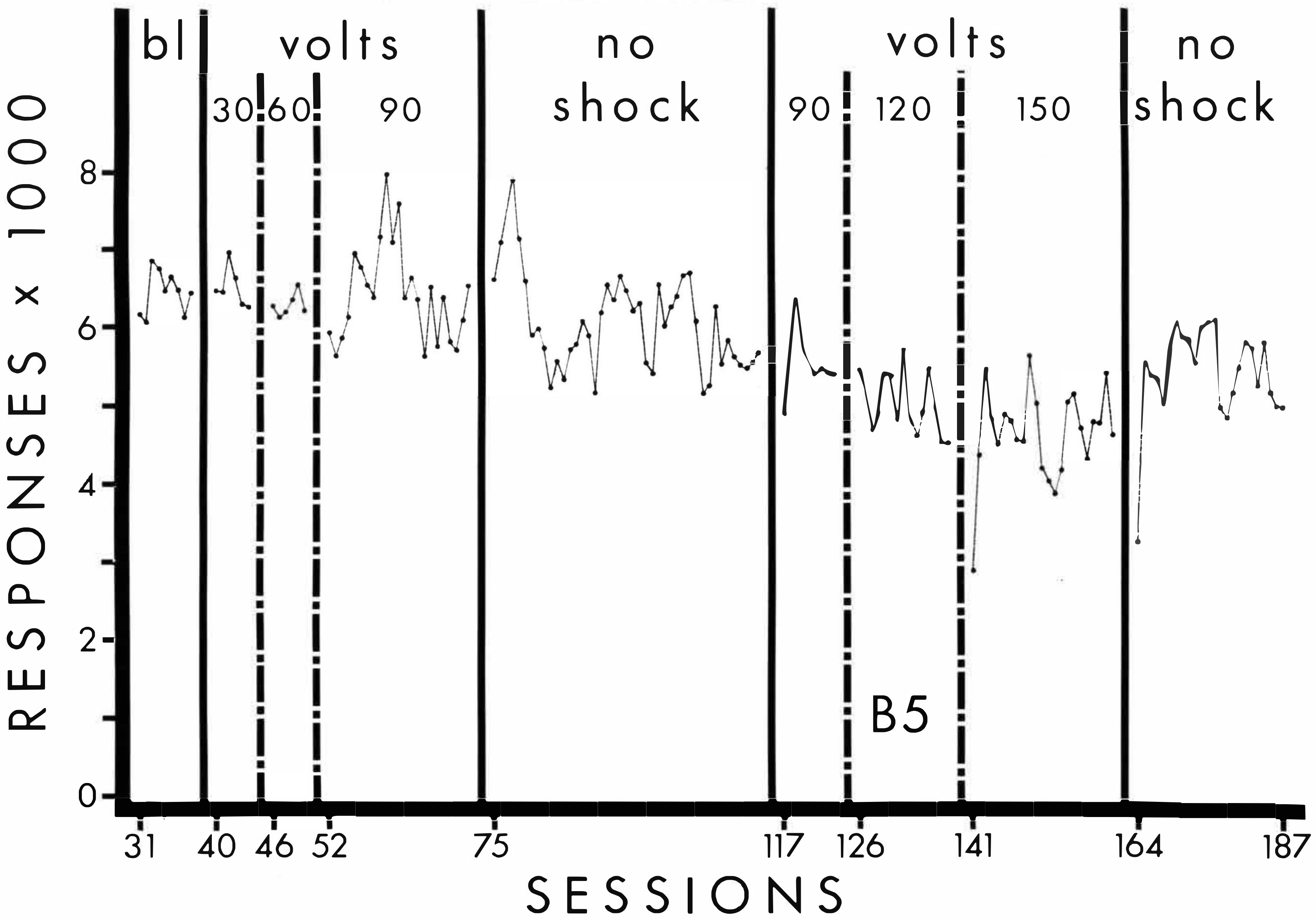

bl
volts
30
no
shock
volts
30
60
no
shk
p
no
shk
RESPONSES x 1000
10
8
6
4
2
0
B3
23
32
51
99
117
140
156
159
172
SESSIONS

punishment(p) schedule using 30 v shocks superimposed on the FI 1 min reinforcement schedule in S+ was effective in reducing S+ responding in session 156 to 56 responses, and similarly reduced responding in session 157 to 24 responses. Complete cessation of responding occurred in session 158. Removal of the punishment contingency in the subsequent phase produced immediate response recovery to the level immediately preceding punishment.

Mean responses for bird B5 during bl was 6448 (Figure 4). Exposure to 30 v and 60 v during S- produced no appreciable change in response frequency. However, the introduction of 90 v resulted in a small response decrement followed by a substantial increase in responding that was asymptotic during session 61 at 7977 (positive contrast). As with all other birds, this initial contrast effect was not maintained and decreased to a mean response frequency of 6084 during the last nine sessions of that phase. The elimination of S- shock during the subsequent phase resulted in an increase in responding during the second, third, and fourth sessions of that phase (sessions 76-68). Responding quickly diminished and remained stable at a mean of 5568 responses for the last five days of that phase. The reintroduction of 90 v of free shock produced little change in the amount of responding. The 120 v and 150 v phases similarly produced little response frequency change except for the first 150 v session (141) when responding decreased markedly to 2884

FIGURE LEGEND

Figure 4: Thousands of responses over sessions for bird B5. Baseline data appear under "bl". The numbers under "volts" indicate the shock voltage level present during S-.


bl
volts
30
60
90
no shock
90
volts
120
150
no shock
RESPONSES x 1000
0
2
4
6
8
31
40
46
52
75
117
126
141
164
187
SESSIONS
B5

responses. Although responding quickly recovered to its previous level, a downward trend from session 120 to 154 resulted in a mean response average of 4820 for the last seven sessions of that phase. Elimination of shock on session 164 produced 3263 responses, unusually low. Responding subsequently increased to levels exceeding 6000 responses during sessions 170, 175, and 176. Responding then decreased to an average of 5111 for the last 10 sessions.

An analysis of the distribution of errors of each bird throughout the experiment revealed no systematic change as a function of shock presentations or shock voltages. The distribution of S+ responding throughout each session broken down into five 24-sec response bins allowed a comparison between distribution of S+ responding. Total responding in the 2 min S+ components was separated during data collection into five 24-sec bins each session.

The subsequent analysis of S+ response distributions compared responding several sessions prior to each new phase or S- voltage level with the first several sessions of each new phase or S- voltage level. No transient contrast was revealed. A similar comparative analysis of S+ response distributions during periods of contrast and (1) the last five sessions of the previous no shock condition and/or (2) the last four sessions of the previous S- shock level also showed no evidence of transient contrast.

DISCUSSION

The outcome of this study must be viewed in light of several methodological considerations.

First, the utilization of errorless discrimination training in this study ensured that all subjects would have no history of reinforcement during S- and minimal S- response rates. The absence of reinforcement in S- and the absence of substantive responding in S- presented a situation in which the aversive properties of S- could be directly manipulated through VT shock without possible confounding by the alteration of positive reinforcement frequency and/or response rate in that component.

Second, the gradual introduction of increasing shock voltages during S- tended to prevent the confounding of contrast effects by generalized disruption of S+ responding due to shocks during S-. However, high shock voltages during S- apparently suppressed S+ responding (birds A2, A3, B5). Similar interactions between shock voltage increments in one component of a multiple schedule with responding in another component were reported by Powell (1971), who found that FR 10 shock punishment superimposed on either a VR or VI reinforcement schedule produced faster responding in the unchanged EXT component (positive contrast) as the shock voltage increased from low to intermediate levels. However, during high shock voltage values, responding in the constant EXT component decreased to low levels. In the present experiment, the S+ response suppression while shocks were delivered in S- was greatest when shock was abruptly increased from 30 v to 150 v for A3, even though previous exposure to gradually introduced 150 v shock has resulted in much faster responding by A3. These results again suggest the efficiency of gradual shock voltage increments in reducing generalized response suppression.

Third, since 30 v response contingent shock during S+ was sufficient to completely suppress S+ responding for B3, shock was clearly punishing for B3, and presumably aversive for the other birds. It was assumed that increasing shock voltage would increase the aversiveness of the shock. Additionally, direct observation of each bird during each of the various S- shock voltages revealed that the magnitude of shock-produced startle responses generally increased with shock voltage.

The major finding of this experiment was that positive behavioral contrast can be produced by increasing the aversiveness of one component of a multiple schedule. Furthermore, contrast effects can be obtained without altering reinforcement rate or response frequency in the changed component. Two birds, A2 and B3, showed initial positive contrast during sessions of 30 v shock during S-, while two other birds, A3 and B5, required 60 v and 90 v of shock during S- respectively to produce similar contrast. Continued exposure to aversive stimuli (shock) at or above the voltage level that initially produced contrast, did not maintain the contrast effects. The diminution of contrast effects with continued discrimination performance has been reported elsewhere (e.g., Terrace, 1966b).

Although between-subject replication was obtained demonstrating positive behavioral contrast with all subjects, only one bird, B3, demonstrated a within-subject replication. The most impressive contrast effect showed by B3 was subsequent to doubling the shock voltage that previously produced contrast by that bird. Although it is not clear why within-subject replication was not more frequently obtained, such results might be due to adaption to the original contrast-producing voltage and subsequent suppression by higher voltages. A systematic replication of the present experiment, modified by a parametric analysis of responding as a function of a variety of even more gradually introduced increments in shock values might provide a clearer answer.

The results of this study are highly supportive of Bloomfield's (1969) "worsening of conditions" hypothesis and Premack's (1969) similar theory that "contrast results if and only if there is a change in the aversiveness associated with one of the components in the schedule (p. 136)." Although both of the theories have greater generality than those offered by Reynolds (1961c) and Terrace (1966a, 1968), neither can satisfactorily account for negative contrast effects when conditions in one component are made absolutely better than before, resulting in a decrease in responding in the constant (unchanged) component. Hitzing's (1969) suggestion that changes in the relative reinforcing or aversive properties of a component determine the production and direction of behavioral contrast broadens the generality offered by the Bloomfield-Premack theories. Thus in the present study, the addition of VT 30 sec shock voltages in S- produced a situation in which the changed component was absolutely more aversive than previously and in which the S+ component, contrasted with the S- component, was relatively more reinforcing than previously.

Further research and theory applications will eventually reveal the most useful and valid concept of contrast and its necessary and sufficient determinants.

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