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AN EXPERIMENTAL STUDY OF BY-PRODUCTS
OF SUCCESSIVE DISCRIMINATION LEARNING
IN THE PIGEON

by

John C. Damron

B.A., California State College at Fullerton, 1968

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in the Department
of
Psychology



JOHN C. DAMRON, 1974

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ABSTRACT

Four experimental groups and a control group of five pigeons each, were trained to successively discriminate a vertical amber line from one oriented either 30 or 60 degrees right. Depending on group, pecks were intermittently reinforced by either 2.5 or 5.0 seconds access to the food hopper. During discrimination formation the S's were provided with a second response key, a peck upon which provided a five second timeout (T.O.) from either the positive or negative stimulus. Rate of response on either the T.O. key or the discrimination key was monitored throughout. After the discrimination had formed all S's were given a post-discrimination generalization test to assess the effects of the experimental procedure on the shape of the generalization gradient. Although peak shift was not obtained, the results significantly support the hypothesis that by-products of successive discrimination training (i.e., gradient shift, behavioural contrast and S- aversiveness) are functions of magnitude of reinforcement reduction and the difference between S+ and S- along the pre-discrimination generalization gradient.

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TABLE OF CONTENTS

Approval	ii
Abstract	iii
Acknowledgments	iv
Table	vi
List of Figures	vii
Introduction	1
Method	11
Results	15
Discussion	18
Footnotes	28
Bibliography	37

TABLE

Table 1. Mean results by groups for gradient shift, behavioural contrast, and S-aversiveness effects.

... 30

LIST OF FIGURES

- Figure 1. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 60-2.5. ... 31
- Figure 2. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 30-2.5. ... 32
- Figure 3. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 60-5.0. ... 33
- Figure 4. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 30-5.0. ... 34
- Figure 5. Magnitude of behavioural contrast as a function of reinforcement magnitude reduction and S+/S- separation for each group. ... 35
- Figure 6. Mean number of timeouts from S- per session for each group. ... 36

INTRODUCTION

In successive discrimination training, a subject is alternately presented with two stimuli, S+, which is correlated with reinforcement, and S-, which is correlated with nonreinforcement or extinction. Three well known "by-products" accompany the development of differential stimulus control in this procedure. These are known respectively as peak shift, behavioural contrast and S- aversiveness. "Peak shift" refers to the displacement of post-discrimination generalization maxima away from S+ in a direction opposite S- (Hanson, 1959).¹ "Behavioural contrast" refers to the increase, during discrimination training, in the rate of responding of an organism in the S+ condition as a function of extinction of responding in the S- condition (Reynolds, 1961; White, 1971).² "S- aversiveness" refers to the tendency of the stimulus correlated with extinction during discrimination training to become "noxious" by that training (Rilling et al, 1969; Terrace, 1971). Operationally, this amounts to the tendency of the experimental organism to "escape" from S-; for example, by pecking a key which produces a brief time-out from S-. According to Terrace, each of these phenomena are relatively impermanent: Behavioural contrast and peak shift disappear with extended discrimination training (Terrace, 1966a) and S- aversiveness gradually diminishes soon after discrimination formation (Terrace, 1971). Moreover, none of these by-products develop if the discrimination is acquired without "errors", that is, responses to S- (Terrace, 1966a).³

With regard to the origin of these by-products Terrace (1971, 1972) has advanced the view that, during successive discrimination training, nonreinforced responding to S- renders it temporarily aversive and inhibitory. The inhibitory gradient centering around S- is then said to interact with the S+ excitatory gradient and force the maxima of the subsequent post-discrimination generalization gradient beyond the S+ value. The view that extinction renders S- at least temporarily aversive is supported by the observation that, during and after standard successive discrimination training, emotional responses (wing flapping, turning away from the response key, etc...) are frequent in the presence of S- (Terrace, 1966c). Such responses were not observed during or after "errorless" discrimination training (Terrace, 1963a). Terrace has also shown that administration of tranquilizing agents to discrimination trained pigeons impaired discrimination performance only in those subjects who had learned the discrimination in the standard or "errorful" fashion (Terrace, 1963b). Specifically, these subjects resumed pecking S- while under the influence of the tranquilizer. Terrace argued that the tranquilizer rendered S- somewhat less aversive and, therefore, less inhibiting with respect to S- responding.

Additional support for Terrace's hypothesis has been provided by Rilling et al (1969) and Terrace (1971). These writers reasoned that, if S- becomes aversive during successive discrimination

training, S's should learn a response which briefly eliminates S-. In these studies S- could be eliminated for brief intervals by a peck on an additional response key. Both of these studies obtained that result. Without exception all S's indeed did learn to escape S- by pecking the additional key. The latter study by Terrace is of special significance since it also demonstrated that pecks on the "escape" or timeout key were strictly dependent upon the contingency between key pecks and timeouts from S- and, therefore, could not be attributed to either frustration produced activity or to the reinforcing properties of stimulus change. This experiment also demonstrated that the timeout response is strong enough to be maintained on a fixed ratio 5 schedule of reinforcement.

A study by Grusec (1968) demonstrated the apparent equivalent effects of non-contingent shocks and large numbers of nonreinforced responses to S-. Grusec trained two groups of pigeons to successively discriminate two wavelength stimuli, the first group learning the discrimination by the standard procedure (i.e., extinction at S-) and the second by Terrace's errorless-fading procedure. In a subsequent generalization test the standard group produced a large peak shift and the errorless group produced a negligible shift. Half of each group thereafter received non-contingent shocks in the presence of S- during continued discrimination training and then, along with the nonshock groups, given a second generalization test. The errorless-shock group produced a substantial peak shift and the

error-shock group produced a larger peak shift than in the first test. The two nonshock groups produced gradients that were only negligibly different from the first test. Grusec interpreted these results as substantially supporting Terrace's hypothesis that S-aversiveness underlies peak shift.

Although Terrace's "S-aversiveness" hypothesis seems substantially well supported by experimental data, his views concerning the determinants of S-aversiveness are not. Terrace has argued that S-aversiveness accrues as a function of response extinction at S- (Terrace, 1966, 1972). That is, if a great number of nonreinforced responses occur in S-, it becomes an aversive stimulus. If only a few or no nonreinforced responses occur in S- (for example, as in errorless discrimination training), S- remains neutral. As Rilling, Kramer and Richards (1973) have pointed out, this implies that S-aversiveness is directly related to the number of extinction responses emitted in its presence. In a recent test of this hypothesis, Rilling et al trained four groups of pigeons to successively discriminate two wavelength stimuli. The groups differed only with respect to the manner in which S- was introduced. The groups were distinguished by whether S- was introduced after few or many "S+ only" sessions ("early vs late") and whether S- was abruptly introduced or gradually faded in ("constant vs progressive"). During discrimination training S's were provided with an additional response key, a peck on which resulted in a brief timeout from S-.

A correlation coefficient between number of S- responses and number of timeouts from S- was then calculated to determine the degree of relationship between these measures for all S's. The resulting correlation coefficient, +.06, led the authors to conclude that "...these data do not support the view that the aversiveness of a stimulus is proportional to the number of unreinforced responses emitted in its presence." Terrace himself has recently been unable to demonstrate a relationship between S- responses and by-products of successive discrimination learning (Terrace, 1973), but has speculated that lack of a simple relationship may be due to individual differences in "frustration tolerance".

It is commonly believed that by-products of successive discrimination learning are a function of the same underlying variables (Terrace, 1966c). This view draws support from the observation that peak shift and behavioural contrast typically covary. That is, they appear and disappear together in "errorful" successive discrimination training and neither appear at all in "errorless" successive discrimination training (Terrace, 1966c). Moreover, any condition which renders one component of a discriminative multiple schedule aversive (i.e., electric shock) produces both phenomena (Brethower and Reynolds, 1962; Grusec, 1968; Terrace, 1968).

Both peak shift and behavioural contrast are most characteristically observed in a successive discrimination procedure following introduction of nonreinforcement or a severely reduced rate of reinforcement in S- (Terrace, 1966). This fact led Reynolds (1961) to suggest that peak shift and behavioural contrast are functions of one of two possible operations: (1) reduction of rate of reinforcement or (2) reduction in the rate of responding. Reynolds favored the first possibility. After reviewing the evidence relevant to both hypotheses, Terrace (1966b) concluded that reduction in rate of responding was the critical operation. Terrace's conclusion apparently stems from a series of experiments he conducted on "errorless" discrimination learning. In these experiments Terrace showed that, under appropriate training conditions, pigeons can learn to successively discriminate a stimulus correlated with reinforcement from a similar stimulus correlated with nonreinforcement with few if any errors, i.e., responses to S-, and that behavioural contrast and peak shift (as well as emotional responses in S-) are seen after errorful, but not errorless, discrimination learning. Terrace implicated response reduction rather than reinforcement reduction apparently because both errorless and errorful discrimination training correlate nonreinforcement with S-, but only errorful training correlates extinction, a reduction in rate of responding, with S- (Terrace, 1966c; Weisman, 1970).

Although Terrace is quick to acknowledge that rate of responding and rate of reinforcement typically covary, he has argued that any operation which reduces rate of responding without reducing rate of reinforcement; for example, a differential reinforcement of low rate procedure (a DRL schedule), will produce peak shift and behavioural contrast (Terrace, 1968). Using such a schedule as one component of a two component multiple schedule (mult VI 60 sec, DRL), Terrace confirmed this hypothesis, but only for those S's who, as a function of prior "S+ only" training, transferred a relatively high rate of response to the stimulus correlated with the DRL schedule (Terrace, 1968, 1972). It should be noted that a DRL schedule requires an interval of at least t seconds between responses for reinforcement. Responses in that interval preclude up and coming reinforcement and reset the interval timer. It follows then that any subject who initially brings a high rate of response (and thus, commensurately short interresponse times) to the stimulus correlated with the DRL schedule will experience some degree of nonreinforcement (i.e., extinction), before adapting to the schedule despite attempts to maintain equal rates of reinforcement between components. Thus, Terrace's experiment is not a convincing, unconfounded demonstration of peak shift and behavioural contrast as sole functions of response reduction.⁴ Since this study, two experiments (Halliday and Boakes, 1972; Wilkie, 1972) have been done in which response rate in the S- component of a multiple schedule was, after baseline

training, reduced by administering food-reinforcement in a "free" or noncontingent manner. Such a procedure reduces rate of response without reducing rate of reinforcement. In neither case was behavioural contrast obtained.

In another study, Nevin (1968) trained pigeons on a two component multiple schedule with equal variable-interval reinforcement in the presence of respectively, a white key and a key illuminated by a black line against a white background. Nevin then reduced responding in the second component of the schedule either by non-reinforcement or by differential reinforcement of its nonoccurrence, technically, a differential reinforcement of other behaviour procedure (a DRO schedule). Rate of reinforcement in the first component and in the DRO remained constant throughout. Behavioural contrast and inhibitory stimulus control along the line orientation dimension were obtained only when responding was reduced by nonreinforcement.

Although it seems that the reinforcement reduction hypothesis is well supported by recent research, and the response reduction hypothesis only feebly so, it remains true that prediction of magnitude of by-products of successive discrimination learning from a knowledge of degree of reinforcement reduction is extremely precarious. To be sure, this might be due to large individual differences in frustration tolerance as Terrace (1972, 1973) has

suggested, but less ambiguous explanations are possible.

The following hypotheses are proposed regarding the determinants of by-products of successive discrimination learning when S+ and S- are from the same stimulus continuum:

(1) Peak shift and behavioural contrast are, following Terrace, functions of S- aversiveness and covary with it.

As S- aversiveness wanes, so also does peak shift and behavioural contrast.

(2) Also, however, S- aversiveness is a function of "conflict", at S-, between generalized excitatory and inhibitory tendencies.⁵ This is due to the fact that S- is initially localized somewhere along the S+ prediscrimination generalization (i.e., excitatory) gradient before initiation of discrimination training and, thus, development of the decremental or inhibitory gradient at S-.

As a function of these opposing tendencies a conflicting or competitive state of affairs exists at S- shortly after discrimination training begins. It is suggested that S- aversiveness is proportional to the height of the S- value on the S+ pre-discrimination generalization gradient. In these terms S- aversiveness, and as a consequence, peak shift and behavioural contrast are functions of overlap between the excitatory gradient centered at S+ and the inhibitory gradient centered at S-. As these gradients steepen

during discrimination training, as they have been shown to do (Farthing and Hearst, 1968; Hearst and Koresko, 1968), gradient overlap diminishes and S- aversiveness subsides. Thus, it is suggested that by-products of successive discrimination learning are not simply functions of reduction of rate or magnitude of reinforcement. They are, instead, functions of reinforcement reduction (and inhibition) in the presence of a stimulus with an initial, specifiable excitatory value. The effects of reinforcement reduction summate with that value to generate by-products. This study was conducted to assess the cogency of this hypothesis.

Since an adequate evaluation of these hypotheses demands an unconfounded assessment of various combinations of two continuous variables (i.e., reinforcement magnitude reduction and stimulus difference), an appropriate experimental tactic is the so-called "randomized block design". In such a design unconfounded assessment of combinations of the two levels of the two independent variables can be obtained by blocking on the two levels of reinforcement reduction magnitude and nesting the two levels of S+/S- differences within each block. Such a design is independently sensitive to each of the possible main effects and the potential interactions. For these reasons, this design (and a control procedure) was employed to investigate the above hypotheses.

METHOD

Subjects:

The S's were 25 male and female white king pigeons reduced to and maintained at 75% of their free feeding weight. Body weight was maintained at this level throughout the experiment by sessional and postsessional feeding.

Apparatus:

The experiment was conducted in a Grason-Stadler three-key operant conditioning station (model E1100PE). White noise was piped into the station from a Grason-Stadler noise generator (model E829E) to mask extraneous laboratory sounds. The center key was transilluminated by a Grason-Stadler multiple stimulus projector (model 20378) equipped to project a 1 inch long, 1/16 inch wide amber line in 12 possible orientations against a black background. The twelve possible orientations were as follows: 0 degrees (vertical), 90 degrees (horizontal), and 15, 30, 45, 60, 75 degrees left and right. These stimuli were initially adjusted as closely as possible for equal brightness and were checked frequently with a photometer to ensure they remained so. During the discrimination phase of the experiment the right response key was operative, illuminated by a white light, and programmed, if pecked, to produce a 5 second timeout (T.O.) from prevailing center key stimulation. It was covered and inoperative during all other phases. The left key was covered and inoperative throughout the experiment. Variable-

interval (VI) reinforcement was programmed by a Grason-Stadler (model 1079) celluloid tape reader. After initial key peck training, center key stimulation was programmed in blocks of one minute duration and separated by a five second inter-stimulus interval during which the experimental chamber was entirely dark.

Procedure:

Phase 1: S's were randomly assorted to four groups consisting of different combinations of S+/S- differences (0 and 30 degrees right or 0 and 60 degrees right) and reinforcement magnitude (2.5 or 5.0 second hopper time). Thus, groups were designated respectively: 30-2.5, 60-2.5, 30-5.0, and 60-5.0. Five S's were also assigned to a control group, designated "C", which was identical to the 60-5.0 experimental group except that pecks on the right key eliminated only its own light for 5 seconds. Responses on this key did not produce timeouts from the discriminative stimuli. S's were then magazine trained and shaped to peck the center key upon which an amber line in the vertical orientation was projected. Following key peck training, responses were reinforced for one session each on multiple VI 15 sec, VI 15 sec and multiple VI 30 sec, VI 30 sec schedules of reinforcement. Thereafter all responses in the baseline phase were reinforced on a multiple VI 60 sec, VI 60 sec schedule of reinforcement. S's were trained on this schedule for 15 consecutive sessions in order to obtain a stable measure of baseline response rate. Baseline was determined by calculating

mean rate of response over the last five sessions.

Phase 2: The timeout key was uncovered and rendered operative and S+ was irregularly alternated with an S- orientation of either 30 or 60 degrees right. The duration of stimulus presentation was 60 seconds. Presentations were separated by a five second inter-stimulus interval during which the experimental chamber was entirely dark. Responses in the S+ condition continued to be reinforced on a variable-interval 60 sec schedule of reinforcement, while all responses in S- went unreinforced. Response rates were monitored in the respective discriminative stimulus conditions. Also, number of timeouts from the respective discriminative stimuli was followed. S's were trained on the discrimination procedure until response rate in the S- condition had fallen to 10% or lower of response rate in S+. Contrast effects were determined by calculating mean S+ response rate over all discrimination sessions to criterion for each subject and then subtracting baseline estimate (phase 1) from this value. The difference was then transformed into percentage increase.

Phase 3: The timeout key was rendered inoperative and a post-discrimination generalization test, consisting of 12 cycles of 9 randomly sequenced line orientations, was administered to all S's. The orientations were 0 degrees (vertical) and 15, 30, 45, 75 degrees left and right. During the test, stimulus duration was reduced from

60 to 30 seconds. All test responses went unreinforced. Response rate in the presence of all stimulus values was monitored.

RESULTS

For reasons not entirely clear, peak shift was not obtained (see Guttman, 1965). However, substantial gradient shifts were obtained. "Gradient shift" refers to the reallocation of generalization test responses from symmetrical to nonsymmetrical distribution around S+ as a function of discrimination training. (It should be noted here that Butter (1963) has shown that pre-discrimination generalization gradients along the orientation of a coloured line are essentially symmetrical.) The relative magnitudes of gradient shift were: group 60-2.5, 2.2%; group 30-2.5, 5.3%; group 60-5.0, 11.3%; and group 30-5.0, 20.2%. In all cases gradient shift was to the left, i.e., in a direction opposite S-. After arcsin transformation, an analysis of variance revealed that those groups differing only in magnitude of reinforcement reduction in S- differed significantly in degree of gradient shift ($F(1/16) = 21.0$, $p < .001$). Those groups differing only in degree of S+/S- separation were also significantly different ($F(1/16) = 5.69$, $p < .05$). An analysis of reinforcement magnitude reduction x stimulus difference revealed no statistically significant differences.

Behavioural contrast effects were obtained in all groups and are as follows: group 60-2.5, 27.0%; group 30-2.5, 42.0%; group 60-5.0, 54.1%; and group 30-5.0, 101.6%. An analysis of variance revealed that those groups differing only in magnitude of reinforce-

ment reduction differed significantly in extent of behavioural contrast effect ($F(1/16) = 10.1, p < .01$). Those groups differing only in degree of S+/S- separation were also significantly different ($F(1/16) = 5.25, p < .05$). An analysis of reinforcement magnitude reduction x stimulus difference disclosed no statistically significant difference.

As operationally defined in the introduction, substantial S-aversiveness effects were obtained in all groups and are, in terms of mean number of timeouts from S- per discrimination session: group 60-2.5, 29.3; group 30-2.5, 48.1; group 60-5.0, 69.3; and group 30-5.0, 86.2. An analysis of variance disclosed that those groups differing only in magnitude of reinforcement reduction differed significantly in number of timeouts from S- ($F(1/16) = 100.83, p < .001$). Those groups differing only in degree of S+/S- separation were also found to be significantly different ($F(1/16) = 21.62, p < .001$). Reinforcement magnitude reduction x stimulus difference was found to be statistically insignificant. Timeouts from S+ were, in every group, negligible (i.e., approaching zero). Hence no analysis was required.

A t-test was done between mean timeouts in group 60-5.0 and a control group identical to 60-5.0 except that no contingency existed between pecks on the second key and timeouts from the discriminative stimuli (group "C"). Mean sessional timeouts for

the former group 69.3, and mean number of pecks on the "second key" for the latter group was 2.1 (range: from 2.6 to 3.2). The comparison between these groups was significant substantially beyond .001.

DISCUSSION

With the exception of peak shift, the results support the hypothesis advanced in the introduction. With regard to the failure to obtain peak shift, it should be noted that peak shift was originally obtained along the wavelength continuum (Hanson, 1959). Subsequent research in which peak shift has been convincingly demonstrated has, by and large, employed wavelength. In this view, Guttman (1965) has argued that peak shift effects may be restricted solely to the wavelength continuum. Although since then at least one researcher has obtained a peak shift along the line orientation dimension (Bloomfield, 1967), several others have failed to do so (Guttman, 1965; Hearst, 1968, 1969). A possible explanation of these rather diverse findings is that peak shift is only a special case of a more general phenomenon.⁶ This view is consistent with Terrace's (1966) suggestion that gradient or "area" shift "...may prove to be more sensitive than the location of the peak as a measure of the effects of discrimination training." In support of his argument, Terrace pointed out that not all S's trained to discriminate successively between two similar wavelength stimuli produce a peak shift in the post-discrimination generalization gradient but that all produce some degree of gradient shift.

The idea that S-aversiveness originates from conflict set up by interacting or overlapping excitatory and inhibitory gradients differs from Terrace's theory in that S-aversiveness results from

development of inhibition (and thus, opposing response tendencies and conflict) at S-. Terrace has taken the opposite view, namely, that inhibition at S- is a function of S- aversiveness.⁷ Since Terrace argues that peak shift is caused by S- aversiveness, it is difficult for him to account for reports of peak shift obtained within the context of aversive conditioning procedures (Siegel, 1967; Cowan, 1968). In this type of study the peak of the post-discrimination generalization gradient is shifted away from an S- which is correlated with the nonaversive condition. S+ is the aversive stimulus. Because interacting excitatory and inhibitory gradients are present in discriminative aversive conditioning procedures (Desiderato, 1967), reports of peak shift effects are readily explicable in terms of the present model.

The present model also has implications for several controversies in the area of discrimination learning which, in large part, revolve around the Hull-Spence theory of discrimination learning. That theory explained discrimination learning in terms of the summation of separate generalization gradients centering, respectively, at S+ and S-, and predicted a decrease in response strength in S+ as a function of discrimination training. What is usually obtained, however, is an increase in S+ response strength (i.e., behavioural contrast). In terms of the present model Hull-Spence discrimination theory failed to take into consideration the transitory emotional ramifications of conflict, or opposing response tendencies, set up

by gradient interaction.

It is commonly believed that Hull-Spence discrimination theory cannot account for peak shift. For example, as recently as 1973 Purtle, in a review of the peak shift literature, has stated that "Spence's (1937) theory of independently generated gradients of excitation and inhibition could not account for peak shift since peak shift could not be described as the summation of the process of simple excitation and inhibition." (Purtle, 1973). (Also, see Herbert and Krantz, 1965; Honig, Thomas and Guttman, 1959.) Regardless of whether this point is strictly true or not, the present account suggests that it is not necessary for the "simple" gradients of inhibition and excitation, as such, to summate into a "peak shifted" post-discrimination generalization gradient. From the point of view of the present theory, peak shift, and for that matter behavioural contrast, are accounted for in terms of a third transitory "aversiveness" gradient emerging out of the interaction or overlap of the simple excitatory and inhibitory gradients. When, as a function of extended successive discrimination training, these simple gradients steepen (Farthing and Hearst, 1968; Hearst and Koresko, 1968), gradient interaction ceases and S- aversiveness, peak shift and behavioural contrast disappear (Terrace, 1966b). It is of some interest to note that the hypothesized emergent gradient may or may not peak at S-. For example, it might peak halfway between S+ and S-. Further research is required to determine the

precise shape and location of this gradient.⁸

As Hearst (1969) has recently pointed out, Terrace's (1963) demonstration of errorless discrimination learning is often considered "embarrassing" for traditional (i.e., Hull-Spence) discrimination learning theory. Terrace has shown that S's who have learned to discriminate two orthogonal stimuli without errors produce a flat generalization gradient when tested along the S-dimension (Terrace, 1966b). S's trained in this fashion also fail to evidence peak shift and behavioural contrast. Because Terrace regards a flat gradient as evidence of lack of inhibitory control, a gradient interaction interpretation is, in his view, precluded.⁹ Since Terrace's study, however, several other researchers have obtained relatively steep inhibitory gradients at S- after errorless discrimination learning (Biederman, 1968; Johnson and Anderson, 1970; Johnson, 1971). Irrespective of this discrepancy in experimental findings, the present account would predict that any procedure which generates a relatively low, flat gradient at S- (eg., Terrace, 1963a) will produce only minimal conflict. Moreover, any discrimination procedure which precludes significant gradient interaction (for example, a fading procedure) will preclude conflict and thus S- aversiveness, peak shift and behavioural contrast.

Perhaps one of the more difficult questions asked of an analysis of the present type relates to the concept, and the nature of, inhi-

hibition. Although it has not been the purpose of the present study to experimentally clarify the notion of inhibition, a few comments are in order. Following Pavlov, a number of psychologists (and in particular Spence, 1937, and Hull, 1952) regarded conditioned inhibition as a principle factor in the reduction of conditioned response strength. Although the latter formulations (and particularly Spence's formulation) were essentially nonphysiological, they have suffered many of the criticisms of Pavlov's vague and overspeculative "physiologizing".¹⁰ Skinner's (1938) criticisms of the concept of inhibition has had a particularly dramatic effect on the area of discrimination learning. Skinner argued that the concept of inhibition was unnecessary and unparsimonious, and that most experimental observations to which the concept is applied can be readily accounted for in terms of reduction of excitation. Skinner also argued that there was virtually no empirical evidence for the existence of a separate inhibitory process. Although Skinner's analysis may have been valid at that time, research since then has, to quote Terrace, "...left little doubt that conditioned inhibition can be measured and that it is a useful concept in describing the formation of a discrimination" (Terrace, 1973; also, see Honig, Boneau, Burstein and Pennypacker, 1963; Jenkins, 1965; Brown and Jenkins, 1967; Hearst, 1968, 1969, 1973; Rescorla, 1969; Hearst, Besley and Farthing, 1970).

In Hearst's (1968; 1969) studies S's received either excitatory,

inhibitory, or excitatory and inhibitory training along the line orientation dimension. In the former two cases, training consisted of reinforcement of responses to a black vertical line against a white background and nonreinforcement of responses to a blank white key, or reinforcement of responses to the blank white key and nonreinforcement of responses to a black line oriented 30 degrees right. Generalization tests were then administered along the line orientation dimension for both groups. S's in group three received food-reinforcement for responses in the presence of the vertical line, but nonreinforcement for responses in the presence of the line tilted 30 degrees right. A generalization test was then administered. Thus, unlike groups one and two, group three S's received both excitatory and inhibitory training along the line orientation dimension. S's in groups one and two were then given successive discrimination training on the intradimensional task group three had initially mastered. That is, responses were reinforced in the presence of a line oriented 90, 60 or 30 degrees right. S's then received a second generalization test. Excitatory and inhibitory gradients obtained in phase one (groups one and two) of the experiment were then algebraically summated to produce quantitative prediction of the form of actual post-discrimination gradients obtained in phase two. In Hearst's words, "The good agreement between obtained and predicted gradients provide support for gradient-interaction theory." (Hearst, 1968).

In the Brown and Jenkins (1967) study, pigeons were trained on a red-green discrimination. When both halves of a split key were green, pecks to the left side of the key were reinforced. When both halves were red, pecks to the right were reinforced. In phase two, a discrimination was trained between the presence (S-) and the absence (S+) of a tone. In phase three, the original red-green discrimination was checked to determine if it was still intact. Then the inhibitory function of the tone was tested by determining to what degree its presence reduced responding to the left side of the response key when both halves of the key were green. This portion of phase three was conducted in extinction. The results clearly demonstrated that the presence of the tone dramatically reduced rate of response to the left side of the green response key. Differential control by red and green over right and left responding was maintained in the absence of the tone. To control for possible "generalization decrement", responding to green in the presence of the tone was monitored in a group of pigeons which had not previously experienced the tone. Rate of response was unaffected by the tone in this group. It was concluded that the tone had become a conditioned inhibitor for experimental S's (Brown and Jenkins, 1967).

Although the viability of the concept of inhibition has been well supported by recent research, the exact origins or determinants of inhibition are not presently clearly understood. The Hull-Spence contention that inhibition accrues as a function of nonreinforcement

or extinction may or may not be true.¹¹ With regard to the question of the origins of inhibition, Catania (1973) has published data supporting his contention that reinforcement has both excitatory and inhibitory effects on behaviour. Catania's view runs counter to Hull-Spence theory which identifies excitation with reinforcement and inhibition with extinction (Spence, 1937; Hull, 1952). Specifically, Catania concluded that "...the rate of a reinforced response is a joint function of (1) an excitatory effect of the reinforcers produced by that class of responses, and (2) an inhibitory effect of the total reinforcers produced by that class and by other classes of responses" (Catania, 1973). Catania's formulation may prove to be a theoretically more promising way to account for the origins of inhibition than more standard formulations.

The present model accounts for behavioural contrast in terms of conflict and S- aversiveness resulting from overlap of excitatory and inhibitory gradients. The magnitude of behavioural contrast is seen to be a function of degree of gradient overlap, as shown in the present study. Although the particular feature of conflict and S- aversiveness responsible for contrast is not presently known with any certainty, it is suggested here that it might be diffuse activation or arousal (cf Duffy, 1941, 1957). This view is consistent with Skinner's (1938) report of increased rate of response in rats as a sole function of dose level of an ingested stimulant.

The present view differs from a more popular theory of behavioural contrast recently described by Nevin (1973) which accounts for behavioural contrast in terms of "post-inhibitory rebound" or "positive induction", terms borrowed from reflex physiology. As an example, Nevin analogizes from the mark-time reflex, a response extensively studied by Sherrington (1906). Sherrington's preparation involved severing the spinal cord of a dog and suspending the animal's hind legs so that they hung unsupported, causing them to swing back and forth. If the dog's tail is stimulated under these experimental conditions, these movements cease. This is an instance of inhibition. If tail stimulation is terminated the mark-time reflex returns at a greater rate and amplitude than before. This is what is known as post-inhibitory rebound. Nevin suggests that something like this underlies behavioural contrast. That is, (1) inhibition accrues at S- during discrimination training, and (2) the transition from S- to S+ comprises the operation for post-inhibitory rebound, and therefore, increased rate of response in S+. As Nevin has remarked, however, "...it is not at all clear that the reduction in the rate of an operant by changing a stimulus from S+ to S- is the same sort of operation as adding an inhibitory stimulus while an eliciting stimulus is still acting..." (Nevin, 1973). Moreover, this account cannot easily explain Terrace's (1963) finding that errorless discrimination training precludes behavioural contrast unless it posits that "something" about errorless procedure circum-

vents inhibitory effects. Since there is no unambiguous demonstration of this possibility (Deutsch, 1967; Biederman, 1967) this claim seems somewhat insubstantial. It also has difficulty accounting for the transitory nature of behavioural contrast (Terrace, 1966e). Whatever the case, a great deal more research is required before a decision can be made as to which model most effectively accounts for contrast and other by-products of successive discrimination training.

A final note is appropriate with respect to peak and gradient shift and their relationship to the present data. It is of some interest to note that, if peak shift can be regarded as a special case of deviation of post-discrimination generalization response allocation from graded to nongraded distribution of responses around S+, a sort of "peak shift" was obtained herein. Gradients 30-2.5 and 30-5.0 both evidenced substantial "nongradedness" in the 30 and 45 degree left (+) portions of the gradient (see Figs. 2 and 4). This tendency was not clearly evidenced in groups 60-2.5 and 60-5.0. It is conceivable that an S+/S- separation of 45 degrees would have produced the "nongraded" post-discrimination generalization phenomena known as "peak shift" (for example, an elevation of test responses at 15 degrees left (+) above those at S+). If this reasoning holds, whether or not peak shift is obtained is strictly a function of the particular drive level, reinforcement magnitude, and S+/S- excitatory difference employed in the experimental procedure.

FOOTNOTES

1. In a more specific sense, "peak shift" refers as well to a displacement of the S- post-discrimination generalization gradient away from S- in a direction opposite S+ (Guttman, 1965).
2. This, more precisely, is positive behavioural contrast. Generically, behavioural contrast is defined as a change of rate in one unaltered reinforcement schedule in a direction opposite to a change in rate in another altered schedule. Contrast is positive if the rate increases in the unaltered schedule and negative if the rate decreases.
3. Terrace's "errorless-fading" procedure differs from the standard procedure in a number of important ways. First, instead of introducing S- after extensive "S+ only" training, S- is introduced into the training procedure immediately after the S+ key peck has been conditioned. Second, the duration of S- is extremely brief (i.e., one second) relative to the duration of S+. Third, the intensity of S- is so low as to be undetectable by a human observer. The duration of the low intensity S- is then gradually increased over successive S- presentations until its duration equals S+ duration. In the next phase, S- duration is reduced to one second and held at that value while the intensity of S- is gradually increased until it is equal to S+ intensity. Finally, the duration of the fully intense S- is gradually increased until it equals S+ duration. Unlike the standard procedure, the "Terrace technique" results in few if any S- responses (i.e., "errors") during successive discrimination training.
4. Terrace, however, claims that reinforcement rate in the DRL component was not lowered at any time. In the absence of a careful shaping procedure the present author is at a loss to explain how this might be accomplished. It should also be noted that Bloomfield (1969) has argued that, even if rate of reinforcement in the DRL component of a multiple schedule is equal to the VI component, the difficult temporal discriminations required by the DRL render it somewhat nonpreferred relative to the VI component. Also, Reynolds (1961) and Bloomfield (1967) have conducted experiments which were very similar to Terrace's and have gotten contrary results.
5. The terms, "inhibition" and "excitation", are used here in a strictly behavioural sense; no neural mechanisms are necessarily implied (however, see Carlton, 1963; Kimble, 1968). In particular these terms refer to the incremental and decremental gradients centering at or about S+ and S- (cf Hearst, Besley and Farthing, 1970).

6. That is, it is possible that peak shift results from a particular confluence of excitatory and inhibitory gradients of specific forms. Otherwise, only gradient shift is obtained.
7. In this sense Terrace does not clearly discriminate between inhibition and affect. Terrace is apparently adhering to Skinner's definition of inhibition as a subset of conditioned emotional responses. To quote, "Failure to reinforce a response is one of the operations depressing reflex strength through an emotion change, and there is little or no distinction to be drawn between inhibition and one kind of emotion." (Skinner, 1938)
8. Subsequent to the present research, the present author has trained one pigeon on a successive discrimination. The procedure was identical to that of the present study except that the S was allowed to take timeouts during the generalization test. Frequency of timeouts from the various test orientations was monitored. A small gradient peaking halfway between S+ and S- was obtained.
9. For a contrary view, see Hearst, Besley and Farthing (1970) and Deutsch (1967).
10. Despite this, however, Hull-Spence discrimination learning theory is still extremely influential in the field of discrimination learning (Riley, 1968).
11. Even if it were not true, that fact alone would not substantially impair a gradient interaction interpretation. Gradient interaction theory simply requires incremental and decremental generalization gradients at, respectively, S+ and S-. Whether the U-shaped gradient at S- has its origin in extinction produced inhibition (Spence, 1937; Hull, 1952) or, as Catania (1973) has argued, in the inhibitory effects of S+ reinforcement, has little bearing on the explanatory efficacy of gradient interaction theory.

Table 1. Mean results by groups for gradient shift, behavioural contrast, and S-aversiveness effects.

	Gradient shift	Behavioural contrast	S-aversiveness (T.O.s from S-)
Group 60-2.5	52.2%	27.0%	29.3
Group 30-2.5	55.3%	42.0%	48.0
Group 60-5.0	61.3%	54.1%	69.3
Group 30-5.0	70.2%	101.6%	86.2
Group C (S-aversiveness control)	N/A	N/A	2.1

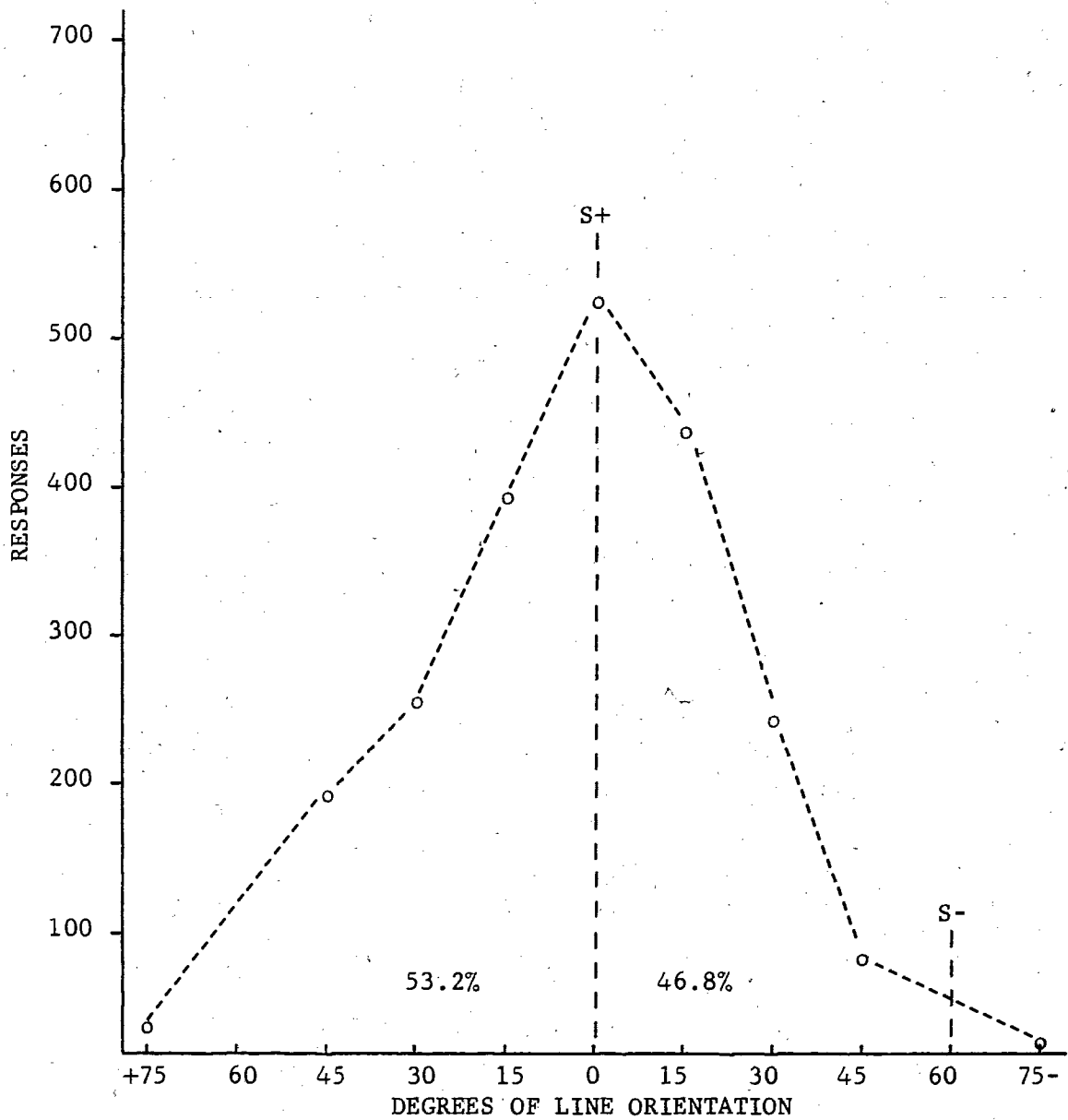


Fig. 1. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 60-2.5.

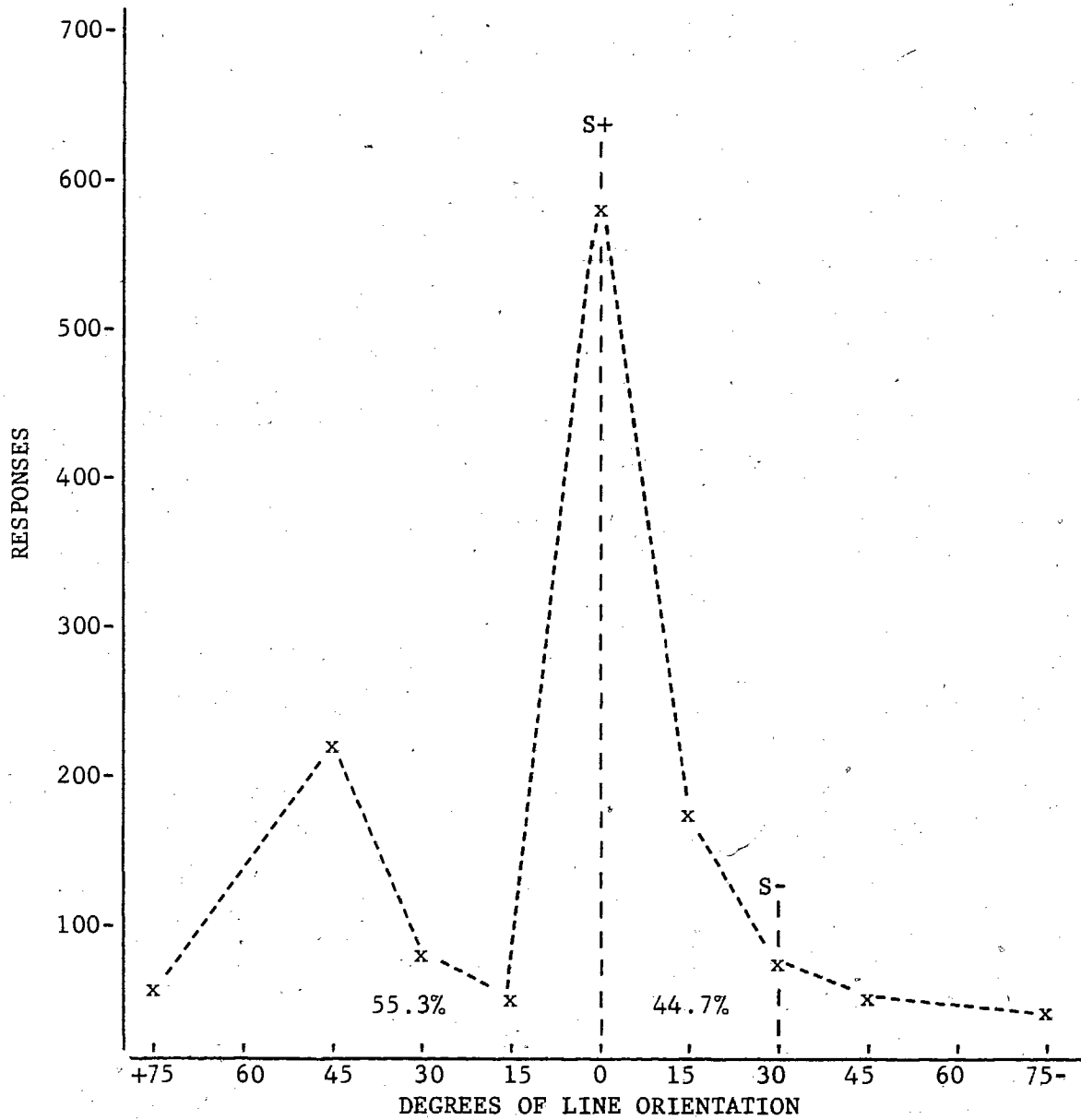


Fig. 2. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 30-2.5.

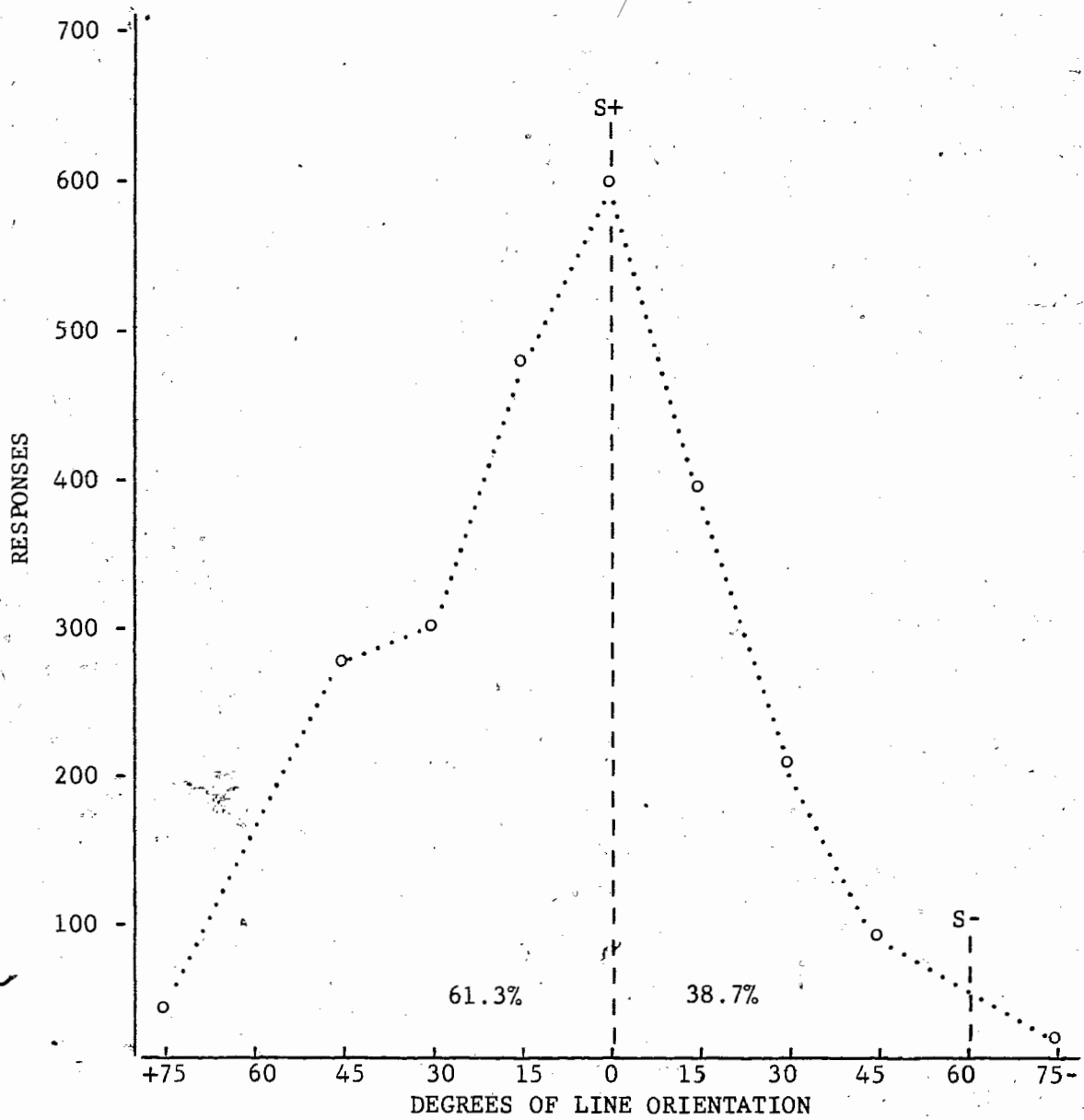


Fig. 3. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 60-5.0.

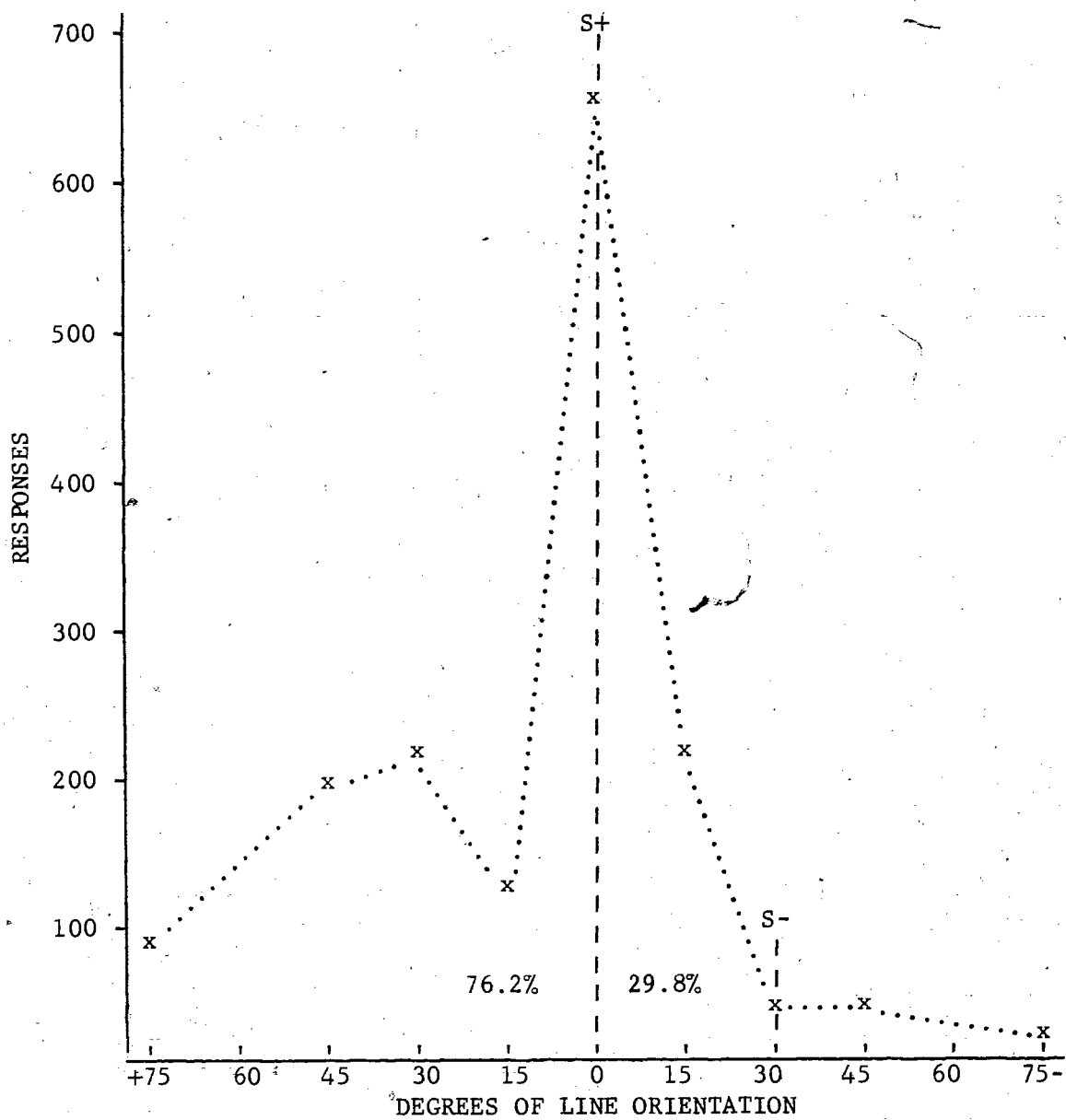


Fig. 4. Shift in post-discrimination generalization gradient distribution as a function of reinforcement magnitude reduction and S+/S- separation for group 30-5.0.

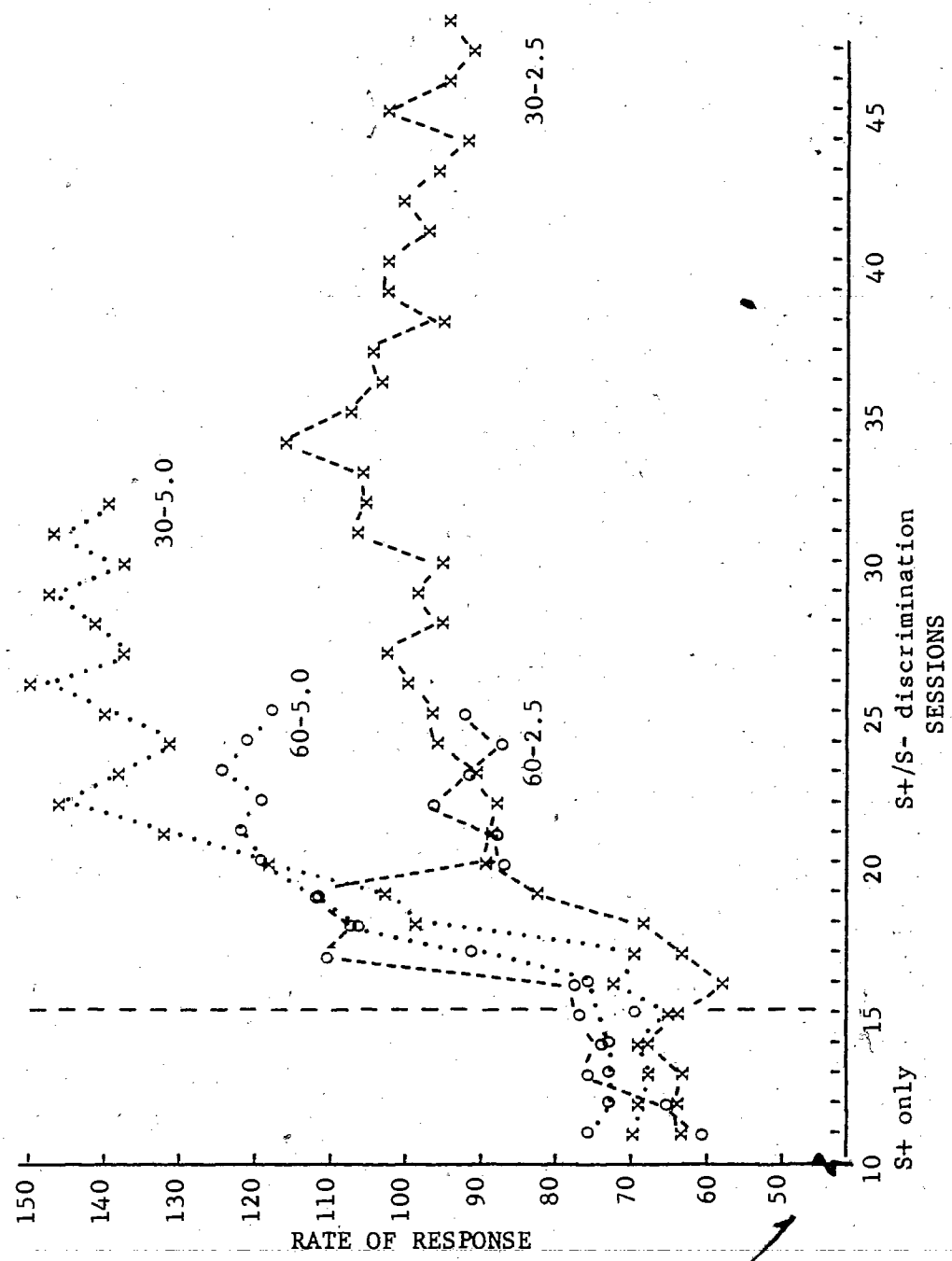


Fig. 5. Magnitude of behavioural contrast as a function of reinforcement magnitude reduction and S+/S- separation for each group.

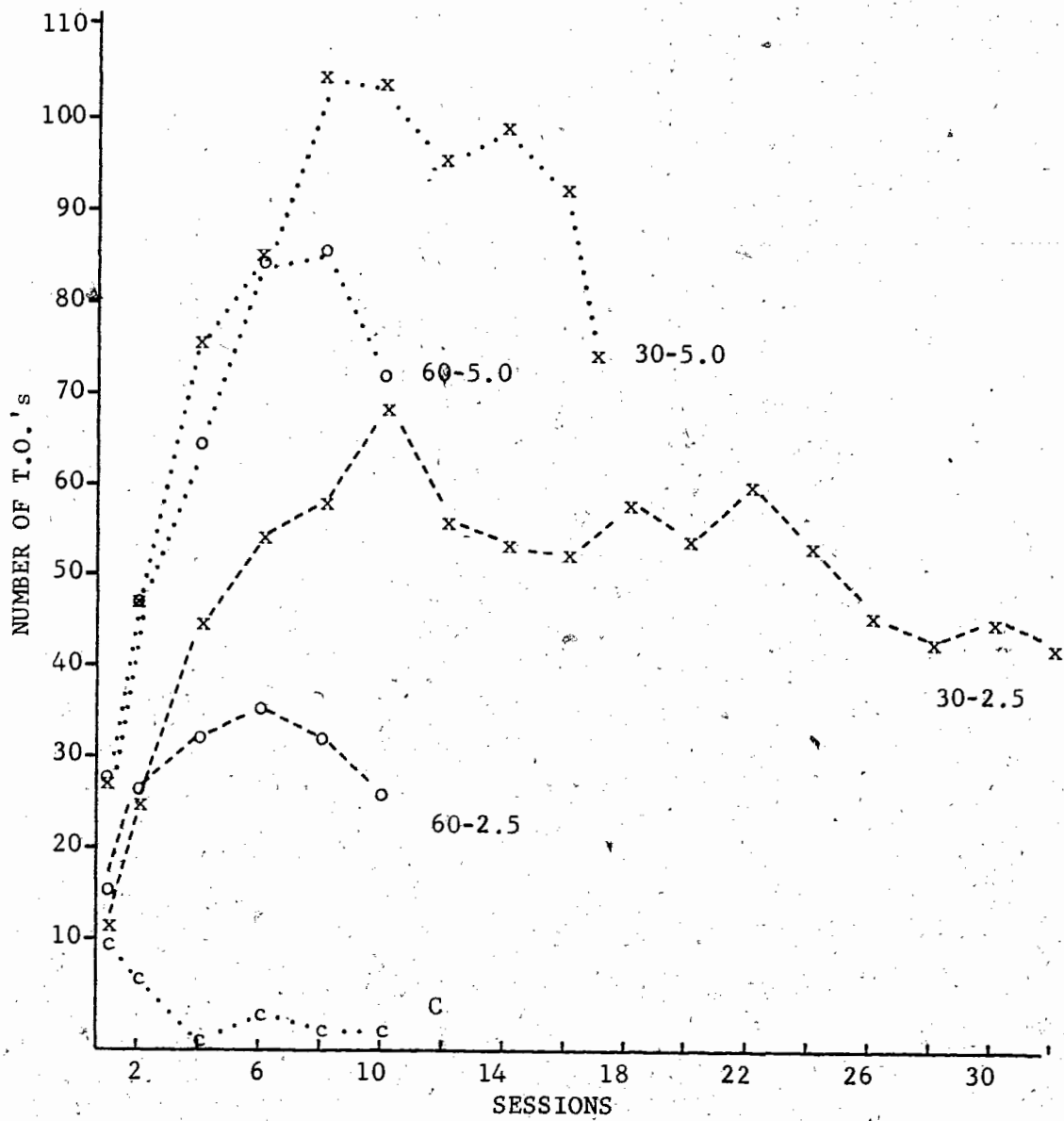


Fig. 6. Mean number of timeouts from S- per session for each group.

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