STIMULUS CONTROL IN PIGEONS AFTER EXTENDED DISCRIMINATIVE TRAINING[1]

Matthew Yarcsower[2] and Karen Curto[3]

Bryn Mawr College

ABSTRACT

The effects of amount of training on conditioned inhibition and on the degree of stimulus control were studied using pigeons.

The ability of an S- associated with non-reinforcement to suppress positive reinforced behavior was acquired very rapidly during discriminative training. Increased S+, S- training appeared to weaken this conditioned inhibitory effect while at the same time more S+ training apparently increased the amount of external inhibition (non-conditioned inhibition) of positively reinforced behavior by a novel stimulus.

Behavioral contrast and incremental generalization gradients along the S- dimension (inhibitory dimensional control) were absent at all stages of training. Behavioral contrast and inhibitory dimensional control are therefore not necessary concomitants of conditioned inhibition by an S-.

A new method of assessing the suppressive effects of stimuli during generalization tests was described.

STIMULUS CONTROL IN PIGEONS AFTER EXTENDED DISCRIMINATIVE TRAINING[1]

Matthew Yarczower[2] and Karen Curto[3]

Bryn Mawr College

The purpose of the present experiment was to study the effect of amount
of training on the degree of control over key-pecking behavior acquired by
each of two stimulus dimensions in the course of discriminative training.
Little work has been done on the problem, and what data there are do not
permit unequivocal conclusions about the relation between stimulus control and
amount of training (Farthing and Hearst, 1969; Terrace, 1966; Yarczower, 1970).

In the first of two experiments reported by Terrace (1966), generalization
gradients after 60 sessions of disriminative training revealed neither a
displacement in the peak of the gradient nor an asymmetry in the distribution
of responses. In the second experiment, 15 discriminative sessions yielded
peak shifts and asymmetrical generalization gradients; continued discriminative
training (60 sessions) eliminated the peak shift but not the asymmetrical
generalization gradients. The lack of asymmetry in the gradients after
extended training in the first experiment could have resulted either from a
lack of inhibitory control by the S- or from highly specific control by the
S-. In the second experiment, in which asymmetry was still present in the
generalization gradients after 60 sessions of discriminative training, it is
likely that inhibitive control by the S- was still present. Terrace could not
directly test this possibility, but Farthing et al. (1968) obtained data
which led them to suggest that greater amounts of discriminative training
yields ". . . increasing specificity of excitatory control by S+ and inhibitory
control by S- . . ." (p. 751). In any case, their data gave no reason to
believe that inhibitory control by S- disappears with extended training.
Yarczower (1970), however, found flat functions in generalization tests
conducted after behavioral contrast had been eliminated, but clear evidence

of inhibitive stimulus control in tests conducted while behavior contrast
was still present.

The present experiment was intended to provide further information
about both excitatory and inhibitory stimulus control after extended
discriminative training. Ideally in such a study, the S+ and S- dimensions
should be orthogonal in order that variations along one dimension in the
generalization tests do not alter the relationships between the two dimensions.
With orthogonal dimensions, the similarity of a stimulus on one dimension to
those on the other dimension is the same at all points on the dimensions
Extended training yields such low levels of responding in the presence of the
S- that the consequent low rates of responding in generalization tests may
render the obtained gradients difficult to interpret. To combat this problem
in the present experiment, stimuli on the S- dimension (line tilt) were
superimposed on a stimulus from the S+ dimension (color). This procedure,
which was intended to increase the overall level of responding during testing,
has other implications which will be considered later.

METHOD

Subjects and Apparatus

Twenty-three experimentally naive Silver King pigeons two to three years
old were maintained at approximately 80% of their free-feeding body weights
throughout the experiment. The experimental chambers were made of Plexiglas
and measured 36 cm x 36 cm x 38 cm. The chamber, within which the pigeon
was placed, was itself within a large chamber made of wood with Celotex
lining that attenuated sounds from outside the chamber. The larger chamber
was 38 cm x 43 cm x 71 cm. The response panel contained a standard Gerbrands
pigeon key that was made of clear Plexiglas and behind which was a projector
made by Industrial Electronic Engineers Co., Model No. 10-1279-1829L, that

could project any one of nine white line tilts and any one of three colors
or any combination of color and white line tilt. A Lehigh Valley Electronics
Co. grain feeder was located below the response key.

Procedure

All pigeons were magazine trained on the first day and given 25 reinforce-
ments on each of two days in which each key peck in the presence of a green
key-light was followed by access to the food magazine for 3 sec.

The birds were divided into two groups, an experimental group of 10
birds that received discriminative training and a control group of 13 birds
that did not receive discriminative training.

Birds in the experimental group began discriminative training following
the second day during which each key peck had been reinforced. A variable-
interval (VI) 1-min schedule of reinforcement in the presence of a green
key-light (S+) was alternated in quasi-random order (Gellermann, 1933) with
an extinction schedule in the presence of a black key with a 5 mm white
vertical line (S-). Each session consisted of 10 periods of S+ and 10
periods of S- presentations. The duration of each stimulus period was 30
sec. There was a 5-sec time-out (TO) period between stimulus presentations
during which the key lights were off and food reinforcers were not available.
The birds in the control group were given 10 periods of S+.

Each group of birds was divided into two subgroups which differed from
one another with respect to when generalization tests were first given. For
one subgroup, generalization tests were carried out after each of three
stages of training: early (after one session); middle (after 25 sessions);
and late (after 60 sessions). The other subgroups was given generalization
tests after only two stages of training, middle and late. Generalization

tests consisted of the presentation of nine test stimuli: green (the S+
during training), orange, red, a vertical white line on a dark background (the
S- for the birds of the experimental group) and five different white line
orientations (vertical, 40 and 80 degrees to the left and right of vertical)
on a green background. Stimulus presentations were separated by 5-sec TO
period and were 30 sec in duration. Food reinforcers were unavailable
during the generalization tests. Each one of the nine test stimuli was
presented six times for a total of 54 test trials.

RESULTS

Fig 1 shows the mean response rates for the subgroups of birds tested
after each of three stages of training. Mean response rates in the presence

---

Insert Fig 1 about here

---

of S+ increased significantly with training. Although the mean response
rates were higher for the experimental than for the control birds during the
first 27 sessions, the differences between the groups were not statistically
significant ($p > 0.05$) as evaluated by a repeated measures analysis of variance
(Bruning and Kintz, 1968).

The upper panel of Fig 2 shows the mean number of responses emitted
during generalization tests with the S+ dimension (color) for both the
experimental and the control birds. A repeated measures analysis of variance

---

Insert Fig 2 about here

---

of these absolute scores yielded F ratios that were statistically significant
for the main effects of Stages of Training ($F_{(2, 24)} = 14.63$, $p < 0.01$, Stimuli,
$F_{(2, 24)} = 47.14$, $p < 0.001$ and for the interaction of Stage with Stimuli,
$F_{(4, 48)} = 14.05$, $p < 0.001$. Thus, there was a significant increase in the

total number of responses emitted during generalization tests with increased training (Stages); a significant generalization gradient (Stimuli); and a significant change in the shape of the generalization gradients with increased training (Stage x Stimuli interaction). In addition, an analysis of the relative generalization gradients (per cent of total responses) shown in the lower portion of Fig 2 yielded a significant Group x Stimuli interaction, $F (2, 24) = 6.29$, $p < 0.01$, which indicates that the mean relative generalization gradients for the experimental birds was steeper than for the control birds. In this analysis, as in that for the absolute number of responses, the main effect of Stimuli, $F (2, 24) = 98.30$, $p < 0.001$ and the interaction of Stage with Stimuli, $F (4, 48) = 3.16$, $p < 0.025$, were both significant.

If an inhibitive stimulus is one that " . . . develops during conditioning the capacity to decrease response strength below the level occurring when that stimulus is absent" (Hearst, Besley, and Farthing, 1970, p. 376), then it should be possible to measure the degree to which a stimulus has acquired inhibitive properties by the extent to which it suppresses operant behavior during generalization tests. In the present study suppression of behavior during tests of generalization was measured by the decrement in responding to a green key light (S+) produced by the superimposition of a line tilt (S-). The amount of suppression was calculated by the ratio A/A+B, in which A refers to the number of responses to the green key-light with superimposed line tilt, and B to the number of responses to the green key-light alone (S+). With maximal suppression the ratio is 0.00; with no suppression it is 0.50. Ratios greater than 0.50 indicate more responding to a line tilt than to the S+ alone.

The suppression ratios of the control birds provide an estimate of the disruptive effects of the introduction of line tilt independently of any

property of line tilt acquired in training. The difference in suppression ratios between the experimental and control birds provides an index of the suppressive effect of line tilt which may be attributed to the discriminative training given the experimental animals.

Insert Fig 3 about here

The suppression ratios during generalization tests produced by the two training procedures are shown in Fig 3. The major difference between the two procedures seems to be early in training, at which point the inhibitive effects of the S- appear to be maximal. A repeated measures analysis of variance of the suppression ratios yielded a signficant Groups effect, $F (1, 12)$ = 7.88, $p < 0.025$ and an interaction of training procedures (Groups) with amount of training (Stages) which was of only marginal significance, $F (2, 24)$ = 3.00, $0.05 < p < 0.10$. A one-tailed t-test (Bruning et al., 1968, p. 112) of the difference between the two groups early in training yielded a significant difference ($p < 0.05$). Differences in mean suppression ratios · between the two groups at each of the other stages of training were not statistically significant by the same test. It is possible that the lack of significant differences between the two groups at the middle and later stages of training was due to the repeated generalization tests under conditions of non-reinforcement which may have produced a greater decrement in responding for the birds given only S+ training than for the birds given discriminative training. Fig 4

Insert Fig 4 about here
---

depicts the suppression ratios for the two groups of birds which were not given generalization tests early in training. A repeated measures analysis of variance of the suppression ratios yielded a significant Groups effect, $F (1, 7) = 7.16$, $p < 0.05$. Neither the main effect of Stimuli nor the interaction of Stimuli x Groups were statistically significant. Differences

in suppression produced by the two training procedures were therefore present
after the early stages of training for birds tested first at the middle stage
of training.

DISCUSSION

The ability of a stimulus associated with non-reinforcement to suppress
behavior can be acquired quite rapidly during discriminative training. In
the present study, the S- became an "inhibitory stimulus" (Hearst et al., 1970)
after the first session of discriminative training which had consisted of five
minutes exposure to the S-. Taken as a whole, the generalization test data
support the suggestion that the inhibitory property of the S- was weakened
with further training. Although the absolute level of behavioral inhibition
increased (the suppression ratio decreased) with further training, it did not
increase differentially for the two groups. Suppression of behavior by the
novel stimulus (the S- for the discriminative training group) increased with
further training for the birds in the control group. This increase in suppression
was correlated with increased rates of responding to the S+ and with increased
excitatory dimensional control (steeper generalization gradients along the S+
dimension). This inhibition is more properly labelled "external inhibition".
Inhibition produced by discriminative training (conditioned inhibition) was
greatest early in training and did not increase with further training. In fact,
it would appear that conditioned inhibition (as reflected by the differences
in suppression between the two training procedures) decreased with further training.

"Inhibitory dimensional control" (Hearst et al., 1970) was absent at
all stages of discriminative training, i.e., variation along the line tilt
dimension did not produce an incremental generalization gradient. The absence
of dimensional control by the line tilt dimension precludes a comparison
between the development of excitatory and inhibitory dimensional control.
A comparison between the degree of excitatory dimensional control and the
conditioned inhibitory property of S- suggests that they may have been negatively

correlated. Suppression by the S- was maximal early in training and weakened with extended training while excitatory dimensional control was weak early in training but increased with extended training. A number of interpretations of different effects of discriminative training have emphasized the critical nature that S- responding plays in producing these effects (Terrace, 1971; Weiss, 1971; Yarczower, Dickson and Gollub, 1966). It should be noted however that changes in the inhibitory property of the S- were unaccompanied by changes in the levels of S- responding. Response rates in S- were at the minimal level almost at the beginning of discriminative training.

The results of the present study bear some similarity to those reported by Davis (1971). In that study, birds given discriminative training yielded no inhibitory dimensional control. Davis also reported that the S- suppressed behavior although it was not possible to assess how much of the response decrement was due to the discriminative training and how much was to external inhibition or to a generalization decrement produced by a novel stimulus.

Finally, increased discriminative training has sometimes eliminated behavior contrast (Terrace, 1966; Yarczower, 1970) and sometimes not (Hearst, 1971). When behavioral contrast has been reduced or eliminated, peak-shifts and inhibitory dimensional control have lessened or disappeared (Terrace, 1966; Yarczower, 1970). When behavioral contrast was present, peak-shifts and inhibitory dimensional control were also in evidence (Hearst, 1971; Terrace, 1966; Yarczower, 1970). The data of the present study can be interpreted to support the additional suggestion that the ability of the S- to suppress behavior does not depend upon the presence of behavioral contrast (as assessed by a comparison of S+ rates between the control and experimental groups) nor upon the presence of inhibitory dimensional control.

REFERENCES

Bruning, J. L., and Kintz, B. L. Computational Handbook of Statistics. Glenview, Illinois: Scott, Foresman, 1968.

Davis, J. M. Testing for inhibitory stimulus control with S- superimposed on S+. Journal of the Experimental Analysis of Behavior, 1971, 15, 365-369.

Deutsch, J. A. Discrimination learning and inhibition. Science, 1967, 156, 988.

Farthing, G. W., and Hearst, E. Generalization gradients of inhibition after different amounts of training. Journal of the Experimental Analysis of Behavior, 1968, 11, 743-752.

Gellermann, L. W. Chance orders of alternating stimuli in visual discrimination experiments. Journal of Genetic Psychology, 1933, 42, 206-208.

Hearst, E. Contrast and stimulus generalization following prolonged discrimination training. Journal of the Experimental Analysis of Behavior, 1971, 15, 355-363.

Hearst, E., Besley, Serena, and Farthing, G. W. Inhibition and the stimulus control of operant behavior. Journal of the Experimental Analysis of Behavior, 1970, 14, 373-409.

Terrace, H. S. Behavioral contrast and the peak shift: effects of extended discrimination training. Journal of the Experimental Analysis of Behavior, 1966, 9, 613-617.

Terrace, H. S. Escape from S-. Learning and Motivation, 1971, 2, 148-163.

Weiss, S. J. Discrimination training and stimulus compounding: consideration of non-reinforcement and response differentiation consequences of S^{Δ}. Journal of the Experimental Analysis of Behavior, 1971, 15, 387-402.

Yarczower, M., Dickson, J. F., and Gollub, L. R. Some effects on generalization gradients of tandem schedules. Journal of the Experimental Analysis of Behavior, 1966, 9, 631-639.

Yarczower, M. Behavioral contrast and inhibitive stimulus control. Psychonomic Science, 1970, 18, 1-3.

FOOTNOTES

[1]This report is based upon a thesis submitted by the junior author to Bryn Mawr College in partial fulfillment of the requirements for the Master of Arts degree. The authors are indebted to R. C. Gonzales for a critical reading of an earlier version of the manuscript. This work was supported by NASA Grant NGR-39-018-002.

[2]Requests for reprints should be sent to Matthew Yarczower, Department of Psychology, Bryn Mawr College, Bryn Mawr, Pennsylvania 19010.

[3]Now at Bureau of Radiological Health, Rockville, Maryland.

CAPTIONS FOR FIGURES

Fig 1. Mean response rate as function of training. The filled circles with a solid line are the rates in S+ for the group given S+, S- training. The open circles are the rates for the group given only S+ training. The filled circles with the dotted line are the rates in S- for the group given S+, S- training.

Fig 2. The upper panel contains the absolute generalization gradients along the S+ dimension (color) at different stages of training for the group given S+, S- training (filled circles) and for the group given only S+ training (open circles).

The lower panel contains the relative generalization gradients based upon the same data as shown in the upper panel.

Fig 3. Generalization gradients of suppression are shown for the group receiving only S+ training and for the group receiving S+, S- training. The suppression ratio was obtained by calculating $\frac{A}{A+B}$, where A refers to the number of responses during generalization tests to the line tilt stimulus superimposed on the S+ (green) and B refers to the number of responses emitted during generalization tests to the S+. Complete suppression is indicated by 0.00 and no suppression by 0.50. More responses to a line tilt than to the S+ stimulus is indicated by ratios greater than 0.50. Generalization gradients at each of the three stages of training are shown for the groups tested early in training and then retested at each subsequent stage.

Fig 4. Generalization gradients of suppression are shown for the group receiving only S+ training and for the group receiving S+, S- training. The suppression ratio was obtained by calculating $\frac{A}{A+B}$, where A refers to the number of responses during generalization tests to the line tilt stimulus superimposed on the S+ (green) and B refers to the number of responses emitted during generalization tests to the S+. Complete suppression is indicated by 0.00 and no suppression by 0.50. More responses to a line tilt than to the S+ stimulus is indicated by ratios greater than 0.50. Generalization gradients are shown after the middle and late stages of training. These groups were not tested early in training.
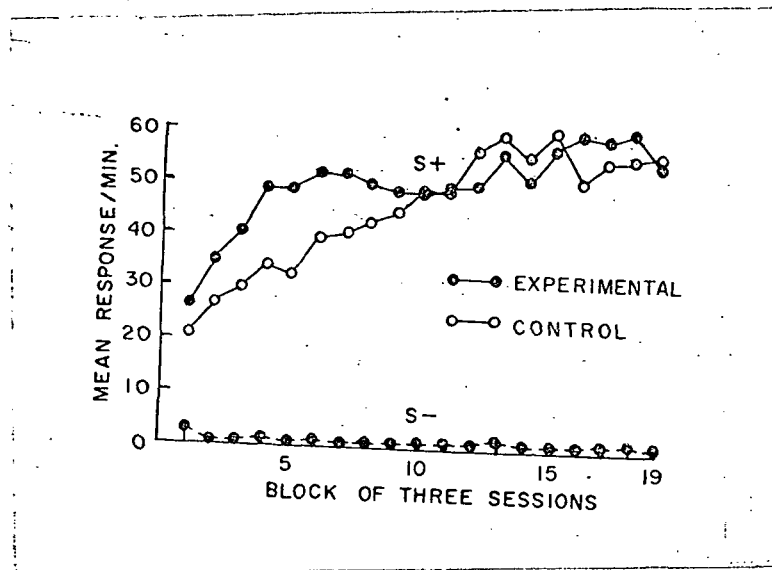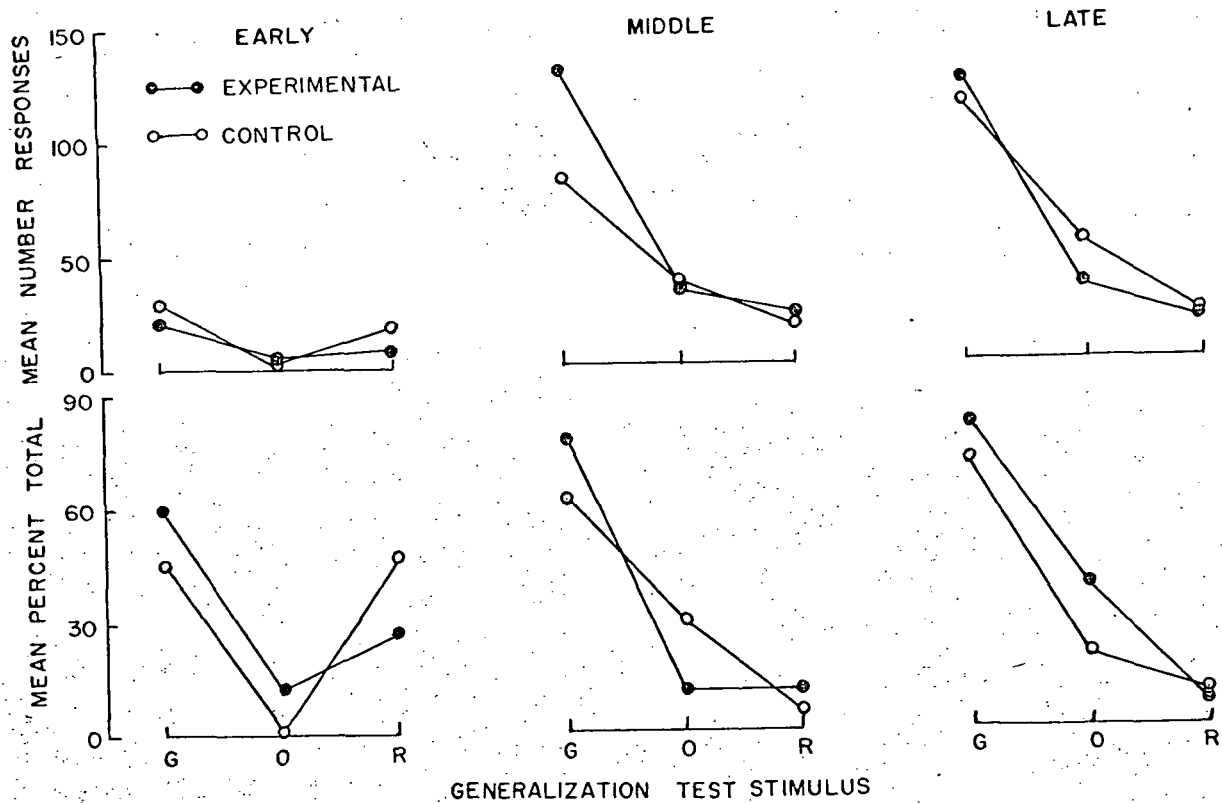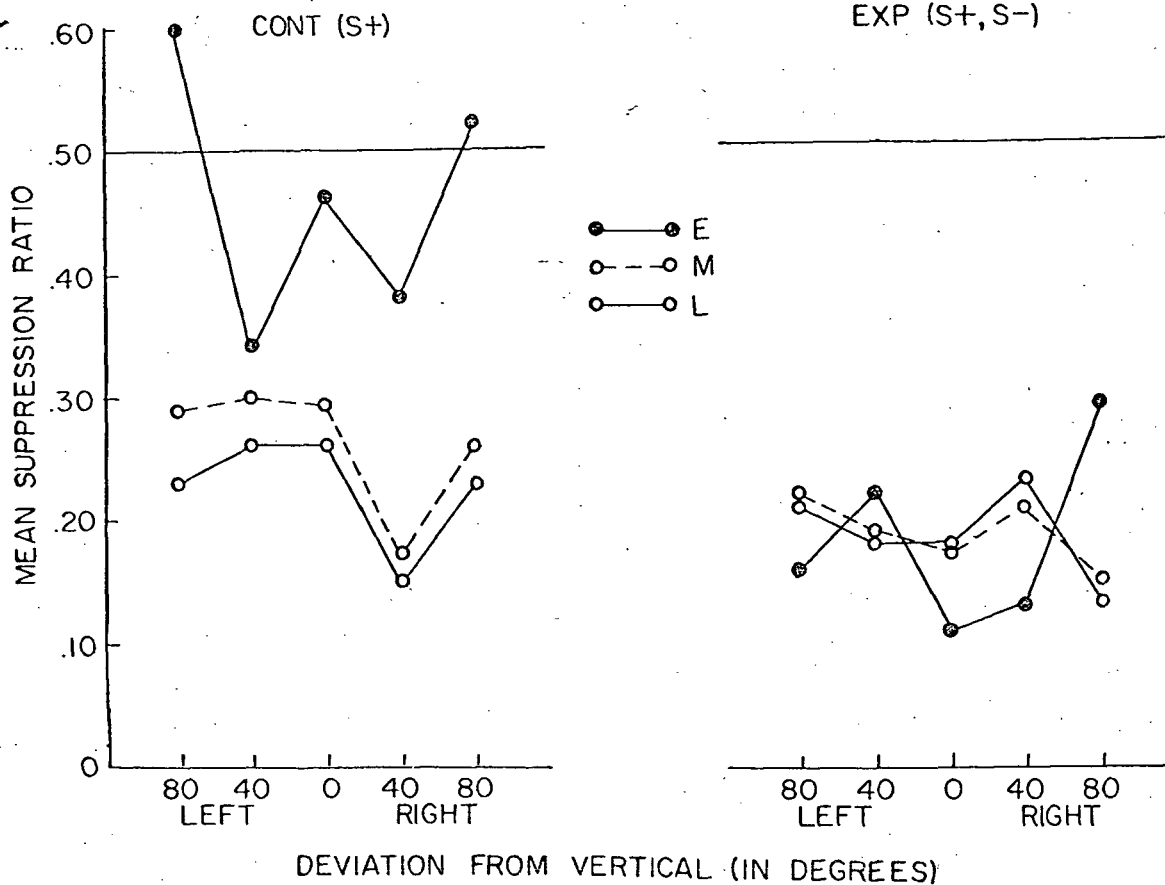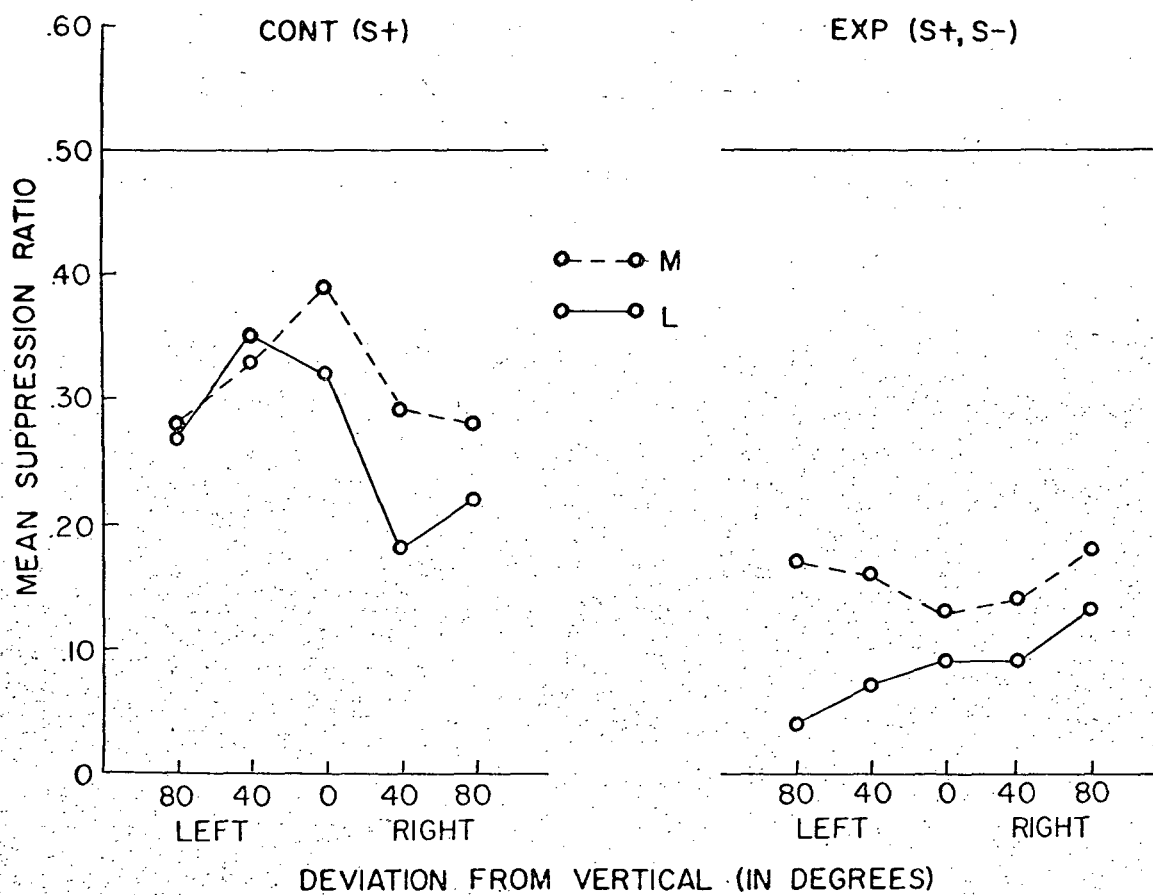
Figure 1

Figure 2

Figure 3

Figure 4