ETHANOL AND STIMULUS CONTROL

by

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Ethanol is the most widely used and abused drug in this country. An estimated 7 per cent of the adult population in the United States manifests the behaviors of alcohol abuse and alcoholism. A full 9 million of the nation's 95 million drinkers may be classified as alcohol abusers and alcoholic individuals (NIAAA, 1971). In 1971, a special report from the Secretary of Health, Education, and Welfare to the U.S. Congress emphasized the need for research into the "identification of the mechanisms by which alcohol acts as an intoxicant affecting the brain and behavior" (NIAAA, 1971, p. 100). Yet, to date, a large amount of our knowledge about the behavioral effects of ethanol stems from anecdotal reports and folklore. For example, it has been widely thought that ethanol reduces tension or anxiety (Higgins, 1976), yet there is little empirical evidence to support this belief (cf. Cappell & Herman, 1972), and investigators are now suggesting alternative explanations of the effects of ethanol on behavior.

Another common presumption has been that ethanol impairs perceptual processes, although again, conclusive research is lacking. However, the ability to reach an understanding of how ethanol might alter perception can be appreciated, to a large extent, in terms of its influence on stimulus control.

Stimulus Control

According to Rilling (1977), "stimulus control is observed when a change in a particular property of a stimulus produces a change in some response characteristic, as in the rate or prob-

ability with which a response occurs" (p. 433). The greater the change in a response characteristic which results from a change in some property of the stimulus, the greater the degree of stimulus control. It is possible to evaluate stimulus control in two ways according to this definition. First, stimulus control may be determined by comparing responding in the presence of a stimulus to responding in that stimulus' absence. The greater the response rate in the presence of the tone than in its absence, the greater the degree of stimulus control. The second way of determining stimulus control involves comparison of responding in the presence of one stimulus to responding in the presence of one or more other stimuli. For example, the difference between response levels to lights of different wavelength could be taken as a measure of stimulus control along the wavelength (hue) dimension.

Clearly, the distinction between these procedures for assessing stimulus control is somewhat arbitrary. Comparison of responding in the presence versus absence of a stimulus might be construed as a comparison between two distinct "stimuli," thus making the first procedure a special instance of the second. Furthermore, in studies in which responding to one stimulus is compared to responding to another stimulus (Procedure 2), it is usually possible to contrast responding during either of those stimuli with responding which occurs during the absence of any stimulus (Procedure 1).

Despite the arbitrary nature of such a distinction, the seperation of these procedures for evaluating stimulus control may

provide a useful basis for empirical examination of the phenomenon. References to stimulus control in this thesis will be primarily concerned with evaluations made using the second procedure, that is, with comparisons made between responding to two or more stimuli. The principal advantage of this restriction is that the second procedure may provide a better means of determining which features of the stimulus control behavior. Since a stimulus may be conceptualized as being composed of multiple features (e.g., intensity, wavelength, spatial location, form, size, etc., in the case of a visual stimulus), examination of responding in the presence as opposed to absence of a stimulus precludes precise delineation of those properties of the stimulus which control responding. However, by systematically varying a single feature or subset of features while keeping other features constant, it should be possible to provide a clearer analysis of the control ascribable to a particular dimension.

Although this thesis will be concerned almost exclusively with instances in which the stimulus under study has been positively correlated with reinforcement (excitatory control), it should be noted that many of the topics discussed also apply to inhibitory control. Inhibitory control is exemplified by those studies (e.g., Honig, Burstein, & Pennypacker, 1963) in which the stimulus has been correlated with the omission of a reinforcer (see Rilling, 1977, for a review).

As Terrace (1966) has pointed out, the term "stimulus control" was proposed as a means of circumventing the lack of clarity involved

in dealing with semantic and conceptual differences between discrimination and generalization. Brown (1965) noted that references to discrimination as a failure to generalize, and generalization as a failure to discriminate have produced much confusion, primarily as the result of a lack of definitional independence of the two terms. The concept of stimulus control somewhat avoids this difficulty by providing a single term which is useful in the empirical description of both discrimination and generalization experiments. Perfectly discriminated responding between two (or more) stimuli may thus be thought of as an example of good stimulus control, whereas total generalization of responding from one stimulus to another represents no stimulus control along that continuum.

The most common method for examining stimulus control has been through the determination of stimulus generalization gradients. In stimulus generalization testing, a stimulus (conditioned stimulus, CS+) which has come to elicit responding through its association with reinforcement is varied along a particular dimension, and the ability of the new stimuli along the dimension of generalization to elicit responses is determined. Frequently used stimulus dimensions include tone frequency or intensity, light wavelength or intensity, and line orientation. A plot of responding as a function of the stimulus' "similarity" to the CS+ is referred to as a generalization gradient. Such plots may depict the number or rate of responses made to each test stimulus (absolute generalization gradient), or they may depict the number of responses made to test stimuli as a

proportion of the responses made to the training stimulus during testing, or as a proportion of the total number of responses made to all stimuli during testing (relative generalization gradients). Stimulus control is said to increase as the slope of the generalization gradient increases. Thus when the slope of the generalization gradient is zero, stimulus control is absent. However, when the generalization gradient is steeply sloping, strong stimulus control is said to be exerted.

Statements about changes in stimulus control in a given experiment may well be at odds with descriptions of the same generalization gradient by more traditional means. For instance, the term "generalization" has commonly been used to describe absolute response strength to a given generalized stimulus (amount of responding above zero) without regard to the level of responding to the CS+. As Brown (1965) has pointed out, by using this definition of generalization, variables which raise or lower the gradient without changing its slope, are said to increase or decrease generalization. According to the definition of stimulus control, however, gradients with identical slopes display equal amounts of stimulus control, regardless of their relative heights.

Other tests of stimulus control have been described by Mackintosh (1977); these include (a) demonstrating that removal of a stimulus which purportedly controls responding is followed by the termination of responding (as mentioned earlier, this procedure will not be considered in this thesis) and (b) the measuring of differential

responding between a stimulus which signals reinforcement and a different stimulus signalling nonreinforcement. The degree of stimulus control is determined by the extent of responding to the reinforced stimulus (CS+) in relation to responding in the absence of the CS+ (in case [a]), or to responding in the presence of the nonreinforced stimulus (CS-, in case [b]). This relationship may be expressed as a difference score, or as a discrimination ratio.

Measurement of Stimulus Control

In the present thesis, stimulus control will be defined by the slope of an absolute generalization gradient. In studies where responding to only two stimuli is measured, the slope of the line which joins response levels to each stimulus will be used to define stimulus control.

In the analysis of manipulations which may alter stimulus control (e.g., drug treatment), it is necessary to consider measurement or scaling problems which might cause difficulty in the interpretation of these experiments. Treatments which cause one group's responding to be in a different part of the measurement scale than responding by another group may produce changes in the slope of a gradient simply as the result of "ceiling" or "floor" effects. For example, in a generalization experiment in which drug treatment results in a CS+ response level which is considerably above that of a nondrug control, a more gradually sloping gradient might be obtained from the higher group due to a ceiling effect at the CS+ response level. When the CS+ measures for the two groups are equal,

differences in stimulus control generally lend themselves to more direct interpretation. This is especially true of cases in which the CS+ response level can be shown to be at a level which is intermediate to the floor and ceiling levels. In such instances, group differences in the slopes of generalization gradients can more confidently be presumed to reflect differences in hypothesized levels of "response strength."

Generalization studies in which response levels for two groups are in different parts of the measurement scale are often interpreted after translating the data to relative generalization gradients. These gradients generally depict responding to the test stimuli as a proportion of each group's CS+ responding, thus ignoring group differences in absolute response levels. The assumption implicit in the use of such relative measures is that a given difference between absolute response levels at different points on the gradient actually reflects a larger difference in underlying "response strength" for subjects responding at low rates than for those responding at high rates. The use of absolute gradients, on the other hand, involves the assumption that a given absolute difference between number of responses to two stimuli represents the same change in underlying "response strength" for subjects responding at low levels as it does for subjects responding at high levels.

To date, neither the absolute nor the relative generalization gradient has been shown to be more meaningful than the other and thus preference for either is somewhat arbitrary. Mackintosh (1974)

has suggested that when two absolute generalization gradients differ greatly in response levels at CS+, "then unless they actually cross over at some test stimuli, it is dangerous to accept at face value any claim that their slopes are significantly different" (p. 494). More generally, in the absence of compelling reasons to favor relative over absolute gradients it is probably best to report at least the absolute data, since these can be used to derive relative gradients and other transformations when it is considered informative to do so.

In order to avoid the conceptual difficulties involved in interpreting absolute versus relative gradients, one might attempt to equate levels of CS+ responding under each treatment condition of interest. By so doing, discrepancies between the two types of gradients should be precluded, since between-group differences in absolute gradients will be of the same form as differences in relative gradients when the groups are equated for absolute CS+ response levels. Moreover, between-group differences resulting from differences in susceptibility to ceiling or floor effects should be minimized, since the gradients of the two groups should lie in approximately the same part of the response scale. Ceiling and floor effects are not necessarily uninvolved, however, when both groups are near the upper or lower limits of the response measure.

In summary, although it is often possible to avoid the scaling problems to which stimulus control tests are susceptible, the present definition of stimulus control does not require the elimination of these measurement difficulties. While it is recognized that neither

relative nor absolute gradients can be asserted to be more meaningful, for conciseness, stimulus control will be defined in this thesis by the slope of an absolute generalization gradient, or in discrimination studies, by the slope of the line which joins CS+ (S+, S^D) response level with the CS- (S-, S^Δ) response level.

Drug Effects on Stimulus Control

The stimulus generalization procedure has been used in numerous instances to investigate the effects of various drugs on stimulus control. Loosely, the procedure is thought to be useful for analyzing an animal's sensitivity to changes in its external environment (cf. Hearst, 1964; Seiden & Dykstra, 1977). Although "stimulus control" was introduced as a purely empirical concept, it is difficult to avoid certain theoretical implications inherent to the phenomenon. Terrace (1966), for example, has noted that many topics such as "perception, psychophysics, thinking, and psycholinguistics are directly suggested by the concept of stimulus control" (p. 272). Nevertheless, whereas overtones of the subjects' processing or evaluation of the stimulus are often tacit to discussions of stimulus control, we are restricted to assessing response output as a measure of the degree of control attributable to a given stimulus dimension. Thus while there are conceivably a number of different ways in which drugs might produce changes in stimulus control (e.g., through changes in any of the following: level of motivation, processing at the sensory receptor, effects on motor systems, associative value of the stimuli, and others), it would be difficult, if not impossible,

to seperate empirically the hypothetical constructs which are thought to be the basis underlying changes in stimulus control. Therefore, some response output must be taken as the ultimate measure of stimulus control.

One of the earliest studies to examine the effects of drugs on stimulus control was performed by Knopf, Worell, and Wolff (1959). Human subjects were presented with a task similar to that used by Brown, Bilodeau, and Baron (1951) in which responding to a light located in a certain place was designated as the "correct" response and responding to peripheral lights arranged in a line was examined. The primary objective of the Knopf et al. experiment was to investigate the effect of anxiety on generalized responding and the subsequent consequence of administering an alleged anxiety-relieving drug, meprobamate. Although not specifically examined by the authors, the inclusion of nonstressed control groups allows for graphic interpretation of drug effects on stimulus control in this task. Whereas both meprobamate and a placebo reliably increased the number of responses, neither treatment changed the shape of the generalization gradient.

Key (1961) used a within-subjects design to evaluate the effects of LSD 25 and chlorpromazine on the generalization of avoidance responding by cats to various frequencies of tones. At the doses used (15 μg/kg LSD and 5 mg/kg chlorpromazine), LSD 25 was found to increase, for all stimuli, the number of responses emitted in extinction, whereas chlorpromazine decreased the overall number of responses.

Neither drug, however, altered the slope of the generalization gradient as compared to gradients obtained with the same animals tested following saline injections.

In a later study, Key (1964) examined the effects of LSD 25 and r-amphetamine on generalization of avoidance responding to three light intensities in cats. Experimental animals were submitted, after appropriate training and retraining, to a total of five extinction procedures, in the sequence: saline, LSD 25, saline, r-amphetamine, saline. Both drugs, at all doses tested, caused an increase in the number of trials to extinction when compared to extinction data from the same animals tested earlier under saline. In further within-subjects comparisons, LSD 25 at a dose of 5 μg/kg flattened the slope of the generalization gradient, whereas doses of 10 and 20 μg/kg left the slopes of the gradients unchanged. Testing under r-amphetamine took place after each animal had been tested under LSD 25, following a second saline control test. With each animal serving as its own control, the three doses of amphetamine (.25, .5, and 1.0 mg/kg) were all found to increase reliably the number of responses to extinction for all stimuli, but more for responses to the conditioned stimulus than for those to the generalized stimuli. Amphetamine was thus concluded to have steepened the generalization gradient.

Interpretation of these data is somewhat complicated, however, by the fact that all statistical analyses reported were within-subject comparisons, whereas comparisons of the drug groups with

the control group (which received saline prior to all five test sessions) were not included. Examination of the data for the control group reveals a reliable alteration in the gradients over sessions, with a flattening of gradients occurring on the second through fourth sessions (when compared to the first-session gradient) and a gradual steepening of the gradient over the next two sessions, so that by the fifth session, the gradient was approaching parity with the initial control gradient. A qualitative comparison of the drug and control groups could thus lead to the conclusion that the flattening of the gradient following administration of 5 μg/kg of LSD 25 was to be expected, whereas maintenance of the initial slope after 10 and 20 μg/kg actually indicated a deviance from the control condition. Furthermore, the gradients obtained during amphetamine testing appear to be markedly steeper than the comparable control gradient, although a statistical comparison was not carried out to evaluate the difference.

It seems plausible, then that both LSD 25 and r-amphetamine could have affected stimulus control. Nevertheless, no conclusive statement can be made since drug responding was statistically assessed only in relation to responding by the same animals in earlier saline sessions; comparisons between drug groups and the saline control group were not made. This same reasoning also applies to Key (1961).

Hanson and Guttman (1961) trained pigeons to respond for food reward by pecking a key illuminated with a monochromatic light, and tested for generalization to various wavelengths of light. For

half of the animals, intramuscular injections of pipradrol, a "behavioral stimulant," preceded generalization tests. Saline injections were administered to control animals. Graphs displaying the number of responses emitted and the percentage of trials with at least one response as a function of wavelength, demonstrated nearly identical generalization gradients for the two groups on the first test day. The gradients for the drugged animals were markedly elevated during the second test due to an increase in responding relative to Day 1. Nevertheless, the slopes of the gradients for the two groups were not significantly different.

Shurtleff and DiMascio (1962) investigated the effects of a tranquilizer, perphenazine, on generalization of responding in male college students. Subjects were instructed to press one key in response to a light of a given wavelength (the positive stimulus, S+) and to respond on another key to any other wavelength. The number of responses to the S+ key was graphed as a function of wavelength. There were no significant differences between gradients obtained after the administration of perphenazine or placebo in a within-subjects comparison.

Another study in which drugs were reported to affect the slope of generalization gradients was performed by Hearst (1964). In an experiment involving three monkeys lever pressing to avoid shock, d-amphetamine, scopolamine and caffeine were found to flatten the slopes of relative generalization gradients to varying degrees in a within-subjects design. The slopes of the absolute gradients,

on the other hand, were generally unaltered by the drug treatments (except for one animal which responded more to most of the generalized stimuli [GSs], but less to the CS under amphetamine). Nearly all drug conditions also produced an overall increase in responding to all stimuli, accounting for the differences between the absolute and relative gradients.

Dykstra and Appel (1970, 1972) conducted two investigations into the effects of LSD on auditory generalization. In the first study, three food-deprived rats were trained to press one lever (the right lever) for sweetened milk in the presence of a 1000-Hz tone and to press another lever (the left lever) in the presence of a 500-Hz tone. Subsequently, the animals were tested in extinction under both drug and no-drug conditions to ten additional tone frequencies. The probability of right lever responses as a function of frequency was plotted as the dependent measure. The drug data indicated that whereas LSD markedly affected reaction times, it did not alter stimulus control, as measured by the slopes of the generalization gradients.

In contrast to the choice measure used in their 1970 study, Dykstra and Appel (1972) examined the effects of LSD on a rate measure of generalization. Rats were trained to barpress for sweetened milk in the presence of one tone (S^D) and to refrain from responding in the presence of another tone (S^Δ). Generalization testing was then conducted by examining response rates in the presence of five additional tones. Testing was conducted under saline

or one of two LSD regimens, .16 mg/kg given in a single dose or .08 mg/kg given three times during the test session. Although both drug regimens were found to reduce the rate of responding, the slope of the gradient generated following three doses of .08 mg/kg was not reliably different from that of the control gradient, regardless of whether rate or percentage of responding was plotted. Nevertheless, the .16 mg/kg dose of LSD produced a disproportionate decrease in responding at the stimuli in the presence of which control rates were high (the stimuli in closest proximity to S^D). The authors conclude, however, that the flattening is probably explained by an overall depression in responding brought about by the high dose. Since responding to stimuli most distant from the S^D was at a minimum prior to drug treatment, it is possible that a dose of drug which lowers response rates would leave responding to these stimuli unaffected while depressing responding to S^D. This kind of "floor effect" is exactly what would be expected if, for example, the dose of drug administered caused a general reduction in the animal's response capabilities.

Perhaps the only study to show reliable drug effects on the slope of absolute generalization gradients was performed by Weisz and Vardaris (1976). Three doses of delta-9-tetrahydrocannabinol (THC) were administered to seperate groups of rats, and the effects on shuttle-avoidance training and auditory frequency generalization were determined. The results indicated that delta-9-THC affects the slope of generalization gradients, with the smallest dose

(2 mg/kg) increasing the slope of the gradient to the largest extent and the highest dose (6 mg/kg) increasing the slope least. Since there were no between-group differences in responding during acquisition, and none of the drug doses reliably changed responding to the CS+ in generalization testing, it is unlikely that the measurement problems discussed earlier were important in the interpretation of this experiment.

In the discussion of their results, the authors suggest that at moderate doses (i.e., 2 mg/kg) delta-9-THC may optimally "sharpen" auditory tuning, thereby increasing perceived contrast among frequencies. Compared with maximum steepening of the gradient at moderate doses, increasingly higher doses of THC would progressively flatten the gradient.

It is also conceivable that Weisz and Vardaris were able to demonstrate drug-induced changes in stimulus control when others were not as a result of methodological differences between their study and those of others investigating drug effects on stimulus control. One notable procedural difference was that Weisz and Vardaris (1976) trained and tested animals in the same drug state, whereas in the other studies reviewed, experimental animals were trained in the nondrug state and tested in the drug state. Whether this difference played a determining role in the test results has yet to be resolved.

With few exceptions then, the slopes of stimulus generalization gradients have not been shown to be affected unambiguously by the

pharmacological actions of various drugs. Stimulus control, as defined by the slope of generalization gradients, thus appears to be a relatively robust phenomenon, not readily susceptible to variations produced by the pharmacological properties of drugs.

Ethanol and Stimulus Control

Studies investigating the effects of ethyl alcohol on stimulus control are limited in number, and are essentially restricted to discrimination studies. Again, the results of various studies appear to contradict one another, with some authors reporting impaired discrimination following ethanol administration, and others finding no effect.

Blough (1956) trained three food-deprived pigeons on a conditional discrimination in which responding to an illuminated key was the correct response in the presence of one stimulus and responding to a dark key was correct in the presence of another stimulus. Correct responses were reinforced with grain presentations. Tests conducted under 1.6 g/kg of ethanol (p.o.) were reported to demonstrate a drug-induced impairment in the percent of correct responses as well as an overall increase in response output.

In an avoidance task in which rats were trained to run to one of two compartments on the basis of an illumination signal, an i.p. dose of 1.0 g/kg of ethanol was found to increase slightly the number of errors relative to saline controls (Hughes & Forney, 1961), although it was not reported whether this increase was significant. No changes in overall responsiveness were observed.

Van Laer, Jarvik and Van Laer (1965) performed a more complex avoidance experiment in which monkeys were required to touch a panel upon the appearance of a dim light only if it was preceded by a bright light. Alcohol, in a dose of approximately 2-3 g/kg (p.o.), was found to both increase the number of responses made to dim lights not preceded by a bright light ("error of commission"), and to decrease the number of responses to dim lights which were preceded by a bright light ("error of omission"). The latter type of error was made to a significantly greater extent than the former.

Holloway and Wansley (1973) investigated the effects of several i.p. ethanol doses on successive visual discrimination performance in rats. Leverpress responses were reinforced with food in the presence of one cue-light condition (S+) and not reinforced in the presence of another (S-). All animals were tested under each of five doses of ethanol, with saline tests occurring on the day prior to and following each ethanol test. Drug effects were evaluated by within-subject comparisons. Four dose-related drug effects were reported: (a) an increase in responding to both stimuli (S+ and S-) at the .5-g/kg dose, (b) no significant effect upon responding at the 1.0-g/kg dose, (c) a significant depression of responding on S+ trials and facilitation of responses on S- trials at the 1.5-g/kg dose, and (d) a depression of both S+ and S- responses at 2.5 g/kg. Furthermore, the lowest dose (.5 g/kg) impaired discrimination performance (as measured by an S+/S- ratio), as did the three

highest doses (1.5, 2.0, 2.5 g/kg). The 1.0-g/kg dose did not affect discrimination performance.

It is noteworthy that in many of the discrimination studies in which stimulus control changes are reported, the outcomes may be obscured by ceiling or floor effects. In the Holloway and Wansley (1973) study, for example, impaired discrimination at the .5-g/kg dose may simply have been due to a ceiling effect, since responding to both S+ and S- increased. Similarly, impaired discrimination at the high doses may have been the result of a floor effect. Only at 1.5 g/kg where S+ responding was depressed and S- responding enhanced, can changes resulting from scaling or measurement artifacts be ruled out.

To date, the only studies to investigate the effects of ethanol on stimulus control have been discrimination experiments. Stimulus generalization procedures have not yet been used to evaluate ethanol's influence on stimulus control. Nevertheless, a study conducted by Moskowitz (1967) is closely related to this line of investigation.

The purpose of the Moskowitz (1967) experiment was to determine the effect of alcohol upon differential brightness thresholds in rats. Rats were presented simultaneously with two lights, one of which was always the same brightness (the standard) and another which was varied in brightness from trial to trial, but was always dimmer than, or the same brightness as the standard. The positions of the two lights were alternated from side to side in a program designed to prevent either side preference or alternation patterns.

Responses to the standard brightness were always reinforced (with milk), whereas responses to the other brightnesses were never reinforced. The percentage of correct responses was graphed for each of the comparison brightnesses, yielding a function similar to a generalization gradient. A .8-g/kg (p.o.) dose of ethanol affected neither the level nor the slope of the function.

Rationale

It appears, then, that in some, but not all discrimination experiments, ethanol may exert an effect on stimulus control. The purpose of the present set of experiments was to examine the effect of ethanol on stimulus control in a stimulus generalization paradigm. This procedure allowed for analysis of the stimulus control attributable to previous reinforcement of one stimulus (CS+) in relation to several other similar stimuli having no history of differential reinforcement. In each experiment, a single dose of ethanol was employed. The doses were selected for their tendency to leave baseline response rates and CS+ responding unaffected. As discussed earlier, this was intended to keep the response levels of drugged and nondrugged animals in approximately the same part of the measurement scale. By doing so, interpretational difficulties resulting from ceiling and floor effects or discrepancies between absolute and relative gradients should be precluded.

Although both experiments utilized classical (Pavlovian) conditioning procedures, they differed in a variety of parameters. In Experiment 1, the stimulus control ascribable to a stimulus

dimension associated with an aversive unconditioned stimulus (US) was studied in a conditioned suppression paradigm. The generalization dimension in the first experiment was tone frequency, and animals were trained in the nondrug state. In Experiment 2, on the other hand, the CS, a vertical line projected onto a pigeon key and varied along a degree-of-tilt continuum, had been paired with an appetitive US. Furthermore, in the second experiment, animals received training in both the drug and nondrug states.

EXPERIMENT 1

In a conditioned suppression (conditioned emotional response, CER) experiment, a stimulus (the CS) which has been paired with shock comes to suppress ongoing operant responding (e.g., barpressing for food reward). Since its introduction by Estes and Skinner (1941), the CER has been the topic of numerous theoretical and empirical analyses (see Blackman, 1977, for a review). The most common interpretation of the phenomenon is that fear is conditioned to the CS, and this fear is responsible for the disruption or suppression of responding. On the assumption that fear is, indeed, conditioned to the CS in this paradigm, then rate of barpressing during the CS should be susceptible to manipulations which affect fear, and in addition, should be governed by the established laws of classical conditioning.

It has been hypothesized that alcohol administration results in tension reduction (cf. Cappell & Herman, 1972). Many investigators have thus reasoned that the ability of alcohol to relieve tension (or fear) should be evidenced in CER experiments as an alleviation of suppression in response to the CS. Nevertheless, numerous authors have reported no effect of ethanol on conditioned suppression other than changes in baseline response rates (Lauener, 1963; Goldman & Docter, 1966; Cicala & Hartley, 1967), even though positive results have been obtained with other drugs hypothesized to reduce tension, in some of the same experiments (Lauener, 1963; Cicala & Hartley, 1967). Cappell and Herman (1972) concluded,

therefore, that studies of alcohol and conditioned suppression fail to support the tension-reduction hypothesis.

Since a conditioning mechanism has been postulated as an explanation for conditioned suppression, the strength of the conditioned aversiveness may be expected to follow the laws of stimulus generalization. Indeed, a number of studies have confirmed that conditioned suppression to a given tone frequency (CS+) will generalize to other tone frequencies (generalized stimuli, GSs). This relationship has been found to hold for both rats (Ray & Stein, 1959; Desiderato, 1964) and pigeons (Fleshler & Hoffman, 1961; Hoffman & Fleshler, 1961; Hoffman, Fleshler, & Jensen, 1963).

The conditioned suppression method of studying stimulus generalization is particularly useful for examining drug effects. Since it is possible to evaluate the drug's influence upon baseline (pre-CS) response rates unrelated to its effects on stimulus control along the generalization continuum under study, nonspecific effects of the drug on responding can be evaluated.

The following experiment was undertaken for two purposes. The primary objective was to examine the effects of ethanol on the generalization of conditioned suppression. In addition to this, the design permitted a further evaluation of ethanol's effects on the CER phenomenon in light of the negative findings to date.

After rats were trained to barpress for food reward, the experiment involved two phases: fear conditioning and generalization testing. Conditioning consisted of tone-shock pairings and was con-

ducted "off-the-baseline," i.e., in an environment which was markedly different from that in which barpress training and generalization testing took place. Throughout the conditioning phase, the animals' deprivation state was also changed; rats were fed before, rather than after experimental sessions. The primary purpose of these general environmental changes was to minimize the conditioning of fear to environmental cues which would be present during generalization testing. Presumably, during testing, since the tones had been the stimuli most consistently associated with shock, they would thus exert the greatest amount of stimulus control.

The tones used during the generalization test sessions (3, 5, 8 kHz) were selected because they share approximately equivalent mean auditory intensity thresholds in rats (Gourevitch, 1965). This was expected to minimize the importance of intensity cues when generalization to the various frequencies was tested.

An attempt was made to reduce the relative importance of the stimulus properties of ethanol in the present experiment by conditioning animals in the nondrug state. The rationale for this procedure was similar to that described earlier for off-the-baseline conditioning. That is, such a procedure should prevent fear from becoming conditioned to the ethanol state. Post training-session injections of ethanol were administered on half of the training and conditioning days to promote the development of tolerance to any motor-impairing effects of the drug. Additionally, the outside exposure to ethanol was also intended to acclimate the animals to

its intoxicating effects, thus diminishing any primary aversive properties that might be attributed to its novelty (cf. Amit & Baum, 1970).

Method

Subjects

The subjects were 24 naive female albino rats (CFE strain, from Charles River, Inc., Wilmington, Massachusetts). They were 65-90 days old at the beginning of the experiment and weighed approximately 200-250 g upon arrival in the laboratory. All rats were caged individually and maintained in constant temperature conditions under a 12-hr light-dark cycle.

The animals were reduced to 80% of their free-feeding weight over the eight days prior to barpress training. After its daily training or test session, each animal was weighed and fed an amount of lab chow adequate to maintain the 80% level. Water was provided ad lib in the home cage throughout the experiment.

Apparatus

Four IOTEK (Iowa City, Iowa) operant chambers (22.5 x 23.0 x 19.0 cm, inside) each housed within an IOTEK sound-attenuating chamber (36.0 x 71.0 x 34.0 cm, inside) were used through the entire experiment. The operant chambers' end panels were constructed from 1.5-mm aluminum sheet, the side walls and ceiling were made of 6-mm clear Plexiglas and the grid floor consisted of 2.4-mm stainless-steel rods spaced at 1.27-cm intervals. During the VI-training and testing phases of the experiment, the grid was covered by 1/8-in

Masonite. A Gerbrands feeder (Model D or D-1) located behind one end panel of each operant chamber, delivered food pellets (45 mg, P.J. Noyes) to a Plexiglas foodcup which was mounted in the center at the bottom of the end panel. To the left of the foodcup, 2.5 cm above the grid floor, was a Gerbrands lever (Model G6312). A ventilation fan was located on the end wall of each of the sound-attenuating chambers and a 6-W houselight was attached to the wall opposite the fan. The houselights of individual chambers (Sylvania 30-V miniature bulbs) were wired in parallel and powered by a 24-V dc power supply. Illumination was maintained at a constant level throughout the VI-training and testing phases of the experiment. During fear conditioning, the amount of power supplied to the bulb was reduced by adding a series resistance of 50Ω to the houselight circuit. Additional apparatus modifications were made during conditioning: The Masonite floor was removed to expose the grid, the rat lever was covered with an aluminum plate to render the lever inaccessible, and the foodcup was covered with electrician's tape.

Two Peerless 2-in (5.0-cm diameter) 8-Ω speakers, wired in series, were mounted on the ceiling of each sound-attenuating chamber, 1 cm above the operant chamber. Tones of 3, 5, or 8 kHz could be delivered individually to each chamber by one of three sine wave generators (Testan, Model 114/04). The average sound pressure level (SPL; re: .0002 dyne/cm^2) of the tones, as measured 3 cm above the grid or Masonite floor in the center of each chamber,

was adjusted to 75 ± 3 dB with a background noise level of 64 ± 2 dB provided by the ventilation fans (SPL measurements via H. H. Scott Sound-Level Meter, Type 450-B, A scale).

The unconditioned stimulus (US) was the 350-V ac output of a step-up transformer fed through a series resistance of 270 kΩ. Upon activation, this circuit delivered a current of approximately .9 mA to a rat whose resistance was 100 kΩ. The shock was delivered to the grid of each chamber by a BRS shock scrambler (Model SC901).

Stimulus presentations and response monitoring were controlled by a PDP-8/F computer.

Procedure

The experimental procedure involved three phases: VI training, fear conditioning, and generalization testing.

On the first day of the experiment, each rat was individually trained to press the lever for food reward. The animals were hand-shaped by the experimenter, using the method of successive approximations, until each animal was pressing reliably. Food pellets were then delivered automatically on a continuous reinforcement schedule until the subject had emitted 100 responses. For the next four sessions (Days 2-5), animals were run on a variable interval (VI) schedule of reinforcement, with sessions lasting until 100 reinforcements had been earned. On a VI schedule, the subject is reinforced for the first response made after a predetermined interval has elapsed. The interval between available reinforcements is varied about the mean value specified by the schedule.

During the first 25 min of Day 2, a VI schedule of 45 sec was in effect. For the remainder of Day 2 and during all subsequent VI sessions, the schedule was VI 1.5 min. Session lengths were approximately 125 min on Day 2, and 150 min on Days 3-5. On Day 5, a procedure designed to adapt the animals to tone presentations was introduced during VI responding. Each of the three tones (3, 5, or 8 kHz) was presented five times in random order. Each presentation lasted 30 sec and the time between the offset of one tone and the onset of the next tone was 9.5 min. No response measures were recorded during this phase.

Off-the-baseline fear conditioning took place on Days 6-8. The procedure is described as "off-the-baseline" since a number of environmental changes (decreased light intensity, grid floor exposed, foodcup and rat lever covered) differentiated the fear-conditioning environment from the environment in other phases of the experiment. As an additional means of altering the stimulus environment during conditioning, the animals' deprivation state was modified by allowing each rat 30-min access to wet food mash prior to conditioning. Immediately following this 30-min period, the animals were placed in the apparatus and the conditioning trials were initialized.

A delay conditioning procedure was used in which the conditioned stimulus (CS) and the US terminated simultaneously. Specifically, a 30-sec tone (CS) coterminated with a 1-sec shock (US). Each session consisted of 12 CS-US pairings interspersed with four CS-alone trials. The 75% partial reinforcement technique was intended

to increase resistance to extinction and thus prolong the effectiveness of the tone as a fear-eliciting stimulus when tested in extinction (cf. Hilton, 1969). For half of the animals, the low frequency tone (3 kHz) served as the CS, whereas the high frequency tone (8 kHz) served for the remaining half. Animals were run four at a time, and in each squad of four, two of the animals were conditioned to the 3-kHz tone and two to the 8-kHz tone. The intertrial interval (ITI) was 8 min, and sessions lasted for 128 min. After the final trial, 1 min elapsed before the animals were removed from the chamber.

On the day after conditioning (Day 9), the original apparatus conditions were reinstated and the animals were given another VI-training session. This was done in order to minimize the possible effects upon responding of any fear that may have become conditioned to the environmental cues which would be present during generalization testing.

Throughout both the VI-training and fear conditioning phases (Days 2-9), animals were given intraperitoneal (i.p.) injections of ethanol (.8 g/kg of a 14.2%, v/v solution in normal saline) or an equivalent volume of physiological saline (7.5 ml/kg), 1.5 hr after the experimental session. Half of each of the two treatment groups described below was randomly selected to receive saline injections on the first injection day (Day 2) and half received ethanol injections. Injected solutions were alternated on subsequent days for all animals; therefore, by the end of Day 9, each animal had received four saline injections and four ethanol injections. This

step was introduced as a means of familiarizing the animals with the injection procedure and of acclimatizing them to the intoxicating effects of ethanol.

For the generalization test phase, the animals were divided into two groups, alcohol-test (Group A) or saline-test (Group S). In each squad of four rats, one of the two animals that had been conditioned to the 3-kHz tone was randomly assigned to Group A, whereas the other animal was placed in Group S. A similar procedure was followed for rats conditioned to the 8-kHz tone. Immediately following i.p. injection of the appropriate solution (.8 g/kg ethanol or normal saline), animals were placed in the apparatus and the test session began.

Animals were tested under the same drug state on each of the two test days (Days 10 and 11). Stimulus-environment conditions were the same during the test phase as they had been during the VI-training sessions. Suppression of VI responding was measured during the presentation of each of the three tones. Regardless of the tone frequency used as CS, all animals were tested with all of the following frequencies: 3, 5, and 8 kHz. Tone presentations lasted 30 sec each, and occurred at 12.5-min intervals, with each tone frequency presented once per session. The order of presentation of tone stimuli was determined as follows. For Day 10 (Test Day 1), each of the six possible sequences of the three tones was randomly assigned to 2 of the 12 animals in each group (Group A and Group S). Thus, each combination was used a total of four times, twice in Group A

and twice in Group S. A similar procedure was used for Day 11 (Test Day 2), with the additional stipulation that no animal receive the same tone as the first test stimulus on both test days. This qualification was undertaken to lessen the possible effects of stimulus order during the generalization test phase.

The number of lever-press responses was recorded during each 30-sec stimulus presentation and during the 30-sec pre-stimulus interval. A suppression ratio was then calculated using the formula DURING/(PRE + DURING) where DURING is the number of responses during the 30-sec stimulus presentation and PRE is the number of responses during the 30-sec pre-stimulus interval. A ratio of .5 indicates no change in response rate during the CS, while 0 represents complete suppression of responding during the CS. The number of responses during a 60-sec post-stimulus period was also recorded.

Approximately 1.5 hr after being returned to its home cage on the first test day, each animal was given an injection of its nontest solution (i.e., animals tested under alcohol were given saline injections and animals tested under saline were given alcohol injections). Thus all animals were equated for experience with ethanol prior to each test session.

Results

Body Weights

At the beginning of the experiment, there were no differences in the weights of the two groups. The mean initial weight before deprivation for Group S was 228 g and for Group A, 231 g [t (22) = .56].

A two-way analysis of variance was performed to evaluate weight regulation over experimental days. The analysis demonstrated no main effect of treatment and no treatment x days interaction. There was, however a reliable change in weight over days [F (10, 220) = 22.03, $p < .001$]. A followup analysis showed this effect to be due primarily to a mean loss of approximately 5 g over the course of the experiment. This 5-g loss represented a deviation of 2.7% from the mean 80% deprivation level of all animals combined.

Response Baseline

In order to ascertain that there were no between-group differences in baseline response rates in the absence of a tone, two comparisons were made. The first measure, and probably the one least influenced by extraneous factors, involved contrasting the number of responses made by Group A during the 30-sec period preceding the first test-stimulus presentation on Test Day 1 with the number of responses made by Group S in the same interval. The means for Groups A and S were 8.9 and 11.5 responses, respectively. These values were not statistically different, as determined by a Mann-Whitney U test [$U = 56$; a nonparametric statistic was used in this instance, because the homogeneity of variance assumption was violated].

The second measure used to check for possible differences in baseline response rates was the mean number of responses occurring across all three 30-sec pre-stimulus periods on each of the two generalization test days. The mean numbers of pre-stimulus responses

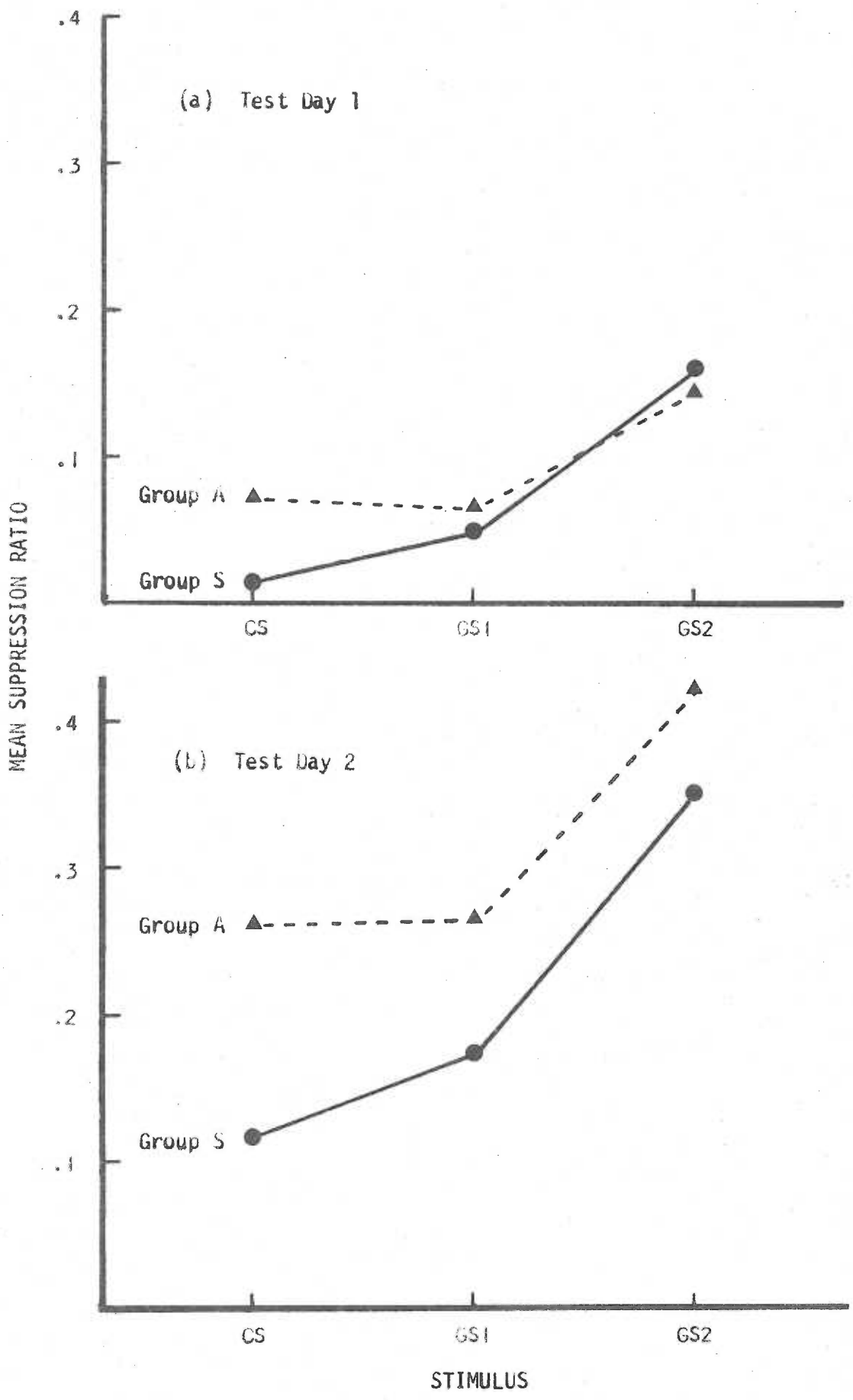
for Group A on Test Days 1 and 2 were 10.1 and 14.7, respectively, whereas the means for Group S were 9.8 and 12.3. Results of a two-way analysis of variance indicated no overall effect of drug treatment and no treatment x days interaction. There was, however a reliable difference between days, with baseline responding significantly higher on the second test day than on the first [F (1, 22) = 13.15, $p < .01$].

Stimulus Generalization

Initially, the alcohol and saline groups were each divided into two subgroups, according to which tone was used as CS during the conditioning phase (3 kHz or 8 kHz). A training tone x test tone x drug treatment analysis of variance was carried out to determine whether these subgroups differed. The results indicated that there was no main effect of training tone on either test day; furthermore, none of the interactions involving the training tones was significant. As a consequence of this finding, the 3-kHz and 8-kHz subgroups were pooled for subsequent statistical analysis. The tone which had been paired with shock was designated as the conditioned stimulus (CS), with the remaining tones assuming the status of generalized stimuli (GS1 or GS2 in order of nearness of the tone's frequency to that of the CS).

The generalization gradients for Test Day 1 are plotted in Figure 1a. From this figure, it can be seen that the conditioning procedure was highly effective in producing suppression of the lever-press response. The mean suppression ratios of the two groups

Figure 1. Generalization gradients for Test Days 1 and 2. Mean suppression to each of the test stimuli is shown for the alcohol (A) and saline (S) treated groups.


.4
.3
.2
.1
(a) Test Day 1
Group A
Group S
CS
GS1
GS2
MEAN SUPPRESSION RATIO
.4
.3
.2
.1
(b) Test Day 2
Group A
Group S
CS
GS1
GS2
STIMULUS

for all three tones on Test Day 1 were .09 for Group A and .07 for Group S. A *t*-test comparing the mean suppression ratios of the alcohol and saline groups to a theoretical value of .5 (no suppression) proved to be highly significant in both cases [*ts* (11) = 14.6 and 26.9, respectively, *ps* < .001]. In addition, it is evident that the greatest amount of suppression occurred to the CS and the least amount to GS2. This observation was confirmed by an analysis of variance in which a reliable effect of test tone was demonstrated [*F* (2, 44) = 5.52, *p* < .01]. There was no difference between the two treatment groups and the treatment x test tone interaction was also nonsignificant. Thus, on Test Day 1, the generalization gradients for the alcohol and saline groups did not differ.

Test Day 2 gradients are shown in Figure 1b. Again, it will be noted that both groups were considerably suppressed in responding during tone presentations, although less so than on the first test day (Group A mean suppression ratio = .31, Group S = .21). Suppression on the second test day was reliably different from a value of .5 for both the alcohol and the saline treatment groups [*ts* (11) = 5.70 and 8.06, respectively, *ps* < .001]. Differential responding to the three stimuli was again evident, with the largest amount of responding (least suppression) occurring during GS2 and the least responding during the CS. This gradient of response strength was evidenced statistically by a significant test-tone effect [*F* (2, 44) = 10.07, *p* < .001]. Once again, the drug treatment x

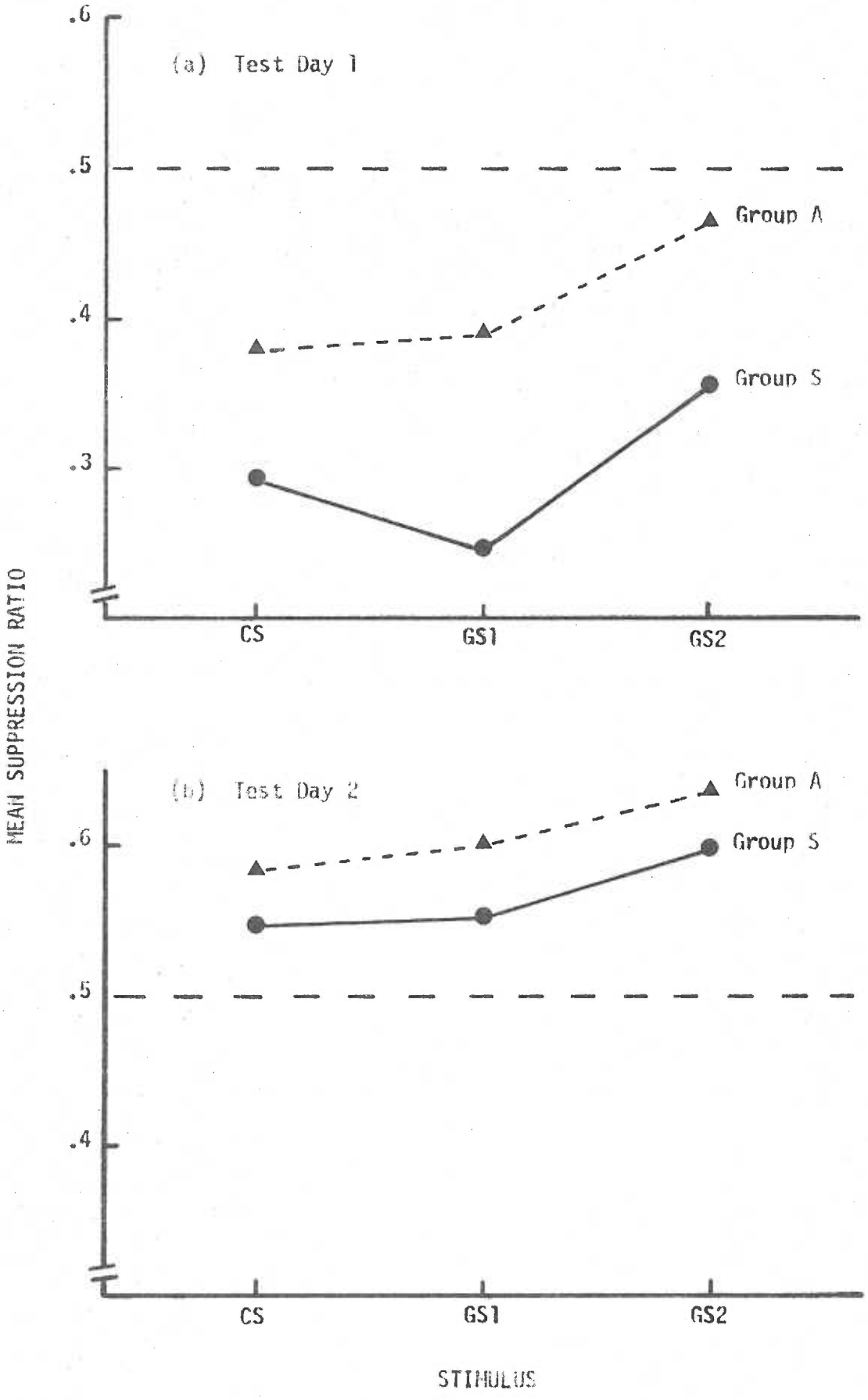
test tone interaction failed to be significant, indicating no between-group differences in the shapes of the generalization gradients. However, there was a reliable main effect of treatment groups on Test Day 2, with the alcohol animals suppressing significantly less than the saline animals [F (1, 22) = 4.33, $p < .05$].

Post-Stimulus Responding

A suppression ratio was calculated using the number of responses during the 60-sec interval following the offset of each tone as the dependent measure. The ratio was of the form 1/2 POST/(PRE + 1/2 POST), where POST is the number of responses in the 60-sec post-tone interval and PRE is the number of responses during the 30 sec prior to tone onset. Again, 0 represents complete suppression and .5, no suppression. Ratios greater than .5 signify an enhancement in responding over pre-tone rates.

Mean post-stimulus suppression ratios for Test Day 1 are graphed in Figure 2a. A treatment x test tone analysis for Test Day 1 revealed no differences due to drug treatment, and no main effect of test tone. The treatment x test tone interaction was also nonsignificant. The suppression ratios for each group were thus collapsed across test tones and the resulting means were compared to a theoretical value of .5 (no suppression). Both groups showed significant suppression following the offset of the stimulus tones on Test Day 1. The mean suppression ratio for the alcohol treatment group was .41 [t (11) = 2.29, $p < .05$], and for the saline group, .31 [t (11) = 3.97, $p < .01$].

Figure 2. Post-stimulus responding. Suppression ratios using response rates during the 60-sec period following tone offset are shown for the alcohol (A) and saline (S) treated groups.


(a) Test Day 1
.6
.5
.4
.3
Group A
Group S
CS
GS1
GS2
(b) Test Day 2
.6
.5
.4
Group A
Group S
CS
GS1
GS2
MEAN SUPPRESSION RATIO
STIMULUS

The data for Test Day 2 are plotted in Figure 2b. Again, there was no treatment effect, no test tone effect, and no treatment x test tone interaction. However, the results did indicate enhanced responding for both groups during the post-stimulus interval, with the mean suppression ratio for both groups significantly greater than .5 [Group S mean = .56, t (11) = 2.20, p = .05; Group A mean = .61, t (11) = 10.01, $p < .001$]. Thus, whereas responding remained suppressed following tone offset on Test Day 1, response rates actually increased over pre-tone levels on the second test day.

Discussion

The results of this experiment fail to provide evidence of any effect of ethanol on stimulus control as defined by changes in the slope of a generalization gradient. However, unlike other experiments in which the effect of ethanol on conditioned suppression has been examined (e.g., Lauener, 1963; Goldman & Docter, 1966; Cicala & Hartley, 1967), the present study appears to support the "tension-reduction hypothesis"; on the second day of testing, animals tested under ethanol demonstrated significantly less suppression of responding to a CS which had been associated with shock than did animals tested under saline.

The failure to find any effect of ethanol on the slope of the absolute generalization gradient is consistent with the results of numerous other studies of drug effects on stimulus control. One possible explanation for these negative results is that drug doses which do not seriously impair responding also do not generally

affect the slope of stimulus generalization gradients. If this were the case, interpretation of changes in stimulus control would likely be obscured by the overall reduction in responding.

While the conditioning procedure in this experiment established reliable generalization gradients on both test days, the between-group differences in level of suppression on Test Day 2 indicate that the attempt to equate groups for CS+ responding may not have been entirely successful. Whereas Test Day 1 suppression levels appear to be equivalent for the two groups, it is possible that floor effects obscured any differences. At the dose used, however, ethanol neither reduced nor increased stimulus control, yet the fact that the overall level of suppression was affected by ethanol on the second test day would suggest that the dose was "behaviorally active."

There are a number of plausible explanations for the decreased suppression by the ethanol group relative to the saline group on the second day of testing. First, it is possible that the differences can be accounted for in terms of a generalization decrement interpretation. Since all animals were conditioned in the nondrug state, and experimental animals were tested in the drug state, it may be argued that the changes in stimulus elements due to drug administration would result in a response decrement (less suppression) by the ethanol-treated animals (cf. Grossman & Miller, 1961). This line of reasoning relies on the assumption that attempts to reduce the relative importance of ethanol's stimulus properties by giving

several pretest injections were unsuccessful. Presumably, the stimulus elements present during testing were sufficiently dissimilar to those present during conditioning to prevent elicitation of the full conditioned-fear response. Although no such differences were apparent on the first test day, as suggested earlier, it is possible that the phenomenon was obscured by a floor effect. Despite the fact that no between-group differences existed on the first day of testing, the more rapid extinction by the alcohol group may yet be consistent with a generalization decrement notion, since performance in extinction has generally been found by others to decline "as the conditions of extinction change from those prevailing in acquisition" (Mackintosh, 1974, p. 408).

Another explanation consistent with the ethanol group's decreased suppression on Test Day 2 is that ethanol actively reduced the animals' fear (cf. Cappell & Herman, 1972). Again, it would have to be argued that a floor effect prevented this on the first test day, although a floor-effect explanation may not be completely tenable for the following reason. Responding by Group S to GS2 on Test Day 1 was at approximately the same level as that group's responding to the CS on Test Day 2. Since that level of responding was sufficiently above a "floor" to be affected by ethanol on the second test day, it stands to reason that ethanol effects would have been apparent, at least for GS2 responding, on the first test day. It seems unlikely, then, that floor effects were completely obscuring drug-induced response changes on Test Day 1.

A third interpretation which might be in accord with the results of this experiment is that the ethanol "state" became a conditioned inhibitor of fear (cf. Cunningham, in press). Although little support for this explanation can be provided by the outcome of the present study, it is possible that the extinction trials on the first test day allowed the ethanol state to become associated with nonreinforcement for Group A. This would be consistent with the finding that while there were no between-group differences on Test Day 1, such differences were evident on the second test day, presumably as a result of learning that occurred on Test Day 1.

EXPERIMENT 2

In the second experiment, an autoshaping procedure was employed to initiate and maintain the pigeon's responding to a stimulus key. Autoshaping involves a Pavlovian conditioning procedure in which the presentation of a CS, typically a keylight, is followed by a US, typically the presentation of food. Repeated pairings of the CS and US result in the development of a conditioned response to the CS, which generally includes pecking the illuminated key. The autoshaping procedure consists exclusively of CS-US pairings, with food reinforcements delivered independently of the animal's behavior. The development and maintenance of the autoshaped key peck has been found to be sensitive to variables which commonly affect other Pavlovian conditioning preparations (cf. Brown & Jenkins, 1968; Williams & Williams, 1969; Jenkins & Moore, 1973; Hearst & Jenkins, 1974).

Following initiation of responding to the illuminated key, the effects of various doses of ethanol on automaintained responding were determined. Since ethanol has been reported to exert both response enhancing and motor impairing effects in pigeons (Leander, McMillan, & Ellis, 1974, 1976), it was necessary to find a dose which would leave CS+ response rates relatively unaffected. Again, this was intended to preclude large between-group differences in response levels during generalization testing. The dose-response assessment was carried out while the birds were performing on a hue discrimination problem. This served three purposes: (a) it

allowed for determination of the effects of the various doses on automaintained key pecking, (b) it permitted examination of ethanol's effects on a simple discrimination task, and (c) in relation to subsequent generalization testing, it provided the pigeons with extradimensional discrimination training which has been shown to steepen the slope of generalization gradients (Thomas, Freeman, Svinicki, Burr, & Lyons, 1970). "Extradimensional discrimination training" refers to a procedure in which animals are trained to respond differentially to two stimuli which lie on a dimension that is orthogonal to that of stimuli to be used during subsequent generalization testing. Following dose-response determination, the pigeons were trained on an interdimensional discrimination task, a procedure which has also been demonstrated to result in sharpened gradients during later generalization tests (Jenkins & Harrison, 1960). In interdimensional discrimination training, reinforcement is correlated with the presence of a stimulus whose features will be varied along a particular dimension during generalization testing (CS+, e.g., a vertical line on a white background), whereas nonreinforcement is correlated with a second stimulus (CS-) which is equally distant from each of the stimuli on the generalization continuum. The CS- generally consists of the absence of CS+ (e.g., a blank, white key). Thus, unlike the previous experiment, the present study involved conditioning with both a reinforced and a nonreinforced stimulus during the training phase. A common explanation for the ability of inter- and extradimensional discrimination training to steepen

generalization gradients is that "such differential reinforcement should neutralize potentially competing incidental stimuli by making them relatively less valid predictors of reinforcement" (Mackintosh, 1974, p. 507). Responding should thereby be restricted to the set of stimuli which has been most reliably paired with reinforcement.

During interdimensional discrimination training, the animals were given ethanol injections prior to half of the experimental sessions, and saline injections prior to the remaining half. At the time of generalization testing, therefore, all animals had equal experience with ethanol. This exposure to ethanol was intended to reduce the influence of the stimulus properties of the ethanol state. By this reasoning, the CS+ should thus become most strongly associated with reinforcement, and the drug state should remain an "extraneous" stimulus.

On each of the three test days, responses were recorded to each of eight stimuli, the CS+ (a set of vertical lines) and seven generalized stimuli (lines tilted to varying degrees). Half of the pigeons were tested following an injection of ethanol, while half were tested following saline injections. Since the dose of ethanol used was selected for its lack of effect on baseline response rates, it was expected that CS+ responding should be the same for both the ethanol and saline test groups.

Method

Subjects

The subjects were eight experimentally naive, domestic pigeons,

three male and five female, obtained through the University of Oregon Health Sciences Center Animal Care Department. They were approximately 7-9 months old upon arrival in the laboratory, and weighed from 387 to 480 g.

Each bird was gradually reduced to 75% of its original weight and was fed an amount of grain adequate to maintain this level following each experimental session. Each animal was individually caged with continuous access to water.

Apparatus

A standard key-pecking panel for pigeons (Grason Stadler Pigeon Station, E1184JA-1) was mounted inside a Grason Stadler Animal Chest (Model E3125 AA-3). With the pigeon station in place, the inside dimensions of the experimental chamber were 33.0 x 33.0 x 36.0 cm. The entire enclosure was housed within an Industrial Acoustic Company walk-in sound-attenuating chamber (inner dimensions: .91 x 1.98 x 1.02 m). Ventilation was provided by fans located in the animal chest and in the sound-attenuating chamber.

The floor of the animal chest consisted of an aluminum tray, containing wood shavings and covered with wire mesh. A food hopper delivered grain through an aperture (5.1 x 4.0 cm) located in the center of the key-pecking panel, 6.0 cm above the floor. A frosted BRS/LVE response key, 2.5 cm in diameter, was situated 23.5 cm above the floor, 3.0 cm to the left of the food hopper aperture. An in-line mini-projector (BRS/LVE, IC 901, with bulb # 1820X), mounted behind the key, was capable of projecting eight different

orientations of line tilts, or white, green or red lighting onto the key. The line tilt displays were comprised of three parallel black lines, approximately 2.0 mm thick, surrounded by a white background and seperated by 3.5 mm (BRS/LVE Film Pattern 715). The eight line tilts consisted of the following orientations, proceeding clockwise from vertical: 0^{o} (vertical), 22.5^{o}, 45.0^{o}, 67.5^{o}, 90.0^{o} (horizontal), 112.5^{o}, 135.0^{o}, and 157.5^{o}.

A houselight was located at the center of the junction of the ceiling and the wall of the chamber, directly opposite the key-pecking panel (bulb # 1820, 28-V dc power supply). The light was diffused by a small piece of lightly sanded clear Plexiglas, and was constantly illuminated except during the operation of the food hopper. When this occurred, the houselight was extinguished and a magazine light (bulb # 1819) illuminated the hopper aperture. Outside light was eliminated by covering the window of the sound-attenuating chamber with an inside layer of construction paper and an outside layer of aluminum foil.

Stimulus presentations and data collection were controlled by a laboratory computer and electromechanical devices.

Procedure

Each experimental session began with a 5-min lights-out period during which no stimuli were presented. A brief lights-out interval also occurred at the end of each session, just before the bird was removed from the chamber.

Magazine training was initiated when the animals had reached

80% of their ad lib weights. On the first day, the hopper was raised and the pigeon was allowed to eat for 30 sec. The food hopper was then activated for 5-sec periods at intervals averaging 30 sec (± 15 sec). Each animal was given a total of 15 hopper presentations on the initial training day. On the following day, the average interval between food presentations was changed to 60 sec (± 30 sec). A total of 40 5-sec hopper presentations was given on that and each subsequent day until every animal had reached a criterion of eating from the raised hopper on 30 successive trials in one experimental session. Once an animal had reached the criterion, it was given no further magazine training. The remainder of the experiment was run with all pigeons at 75% of their free-feeding weights.

Phase 1: Discrimination training and dose-response determination. An autoshaping procedure was used to initiate responding to the lighted key (cf. Hearst & Jenkins, 1974). A red light was projected onto the response key for 5 sec after which the food magazine was activated for 5 sec. A total of 36 trials was given daily, with a variable intertrial interval (ITI) of 60 sec (range = 30-90 sec). Three days of autoshaping were followed by three nonexperimental days on which the pigeons were merely weighed and fed. Subsequently, each animal was given an additional day of autoshaping trials with the red key. On this and each subsequent no-drug day, the birds were given injections of physiological saline (10 ml/kg, i.p.) immediately prior to being placed in the apparatus. These injections were intended to adapt the animals to the injection procedure.

All of the pigeons had attained a consistent level of responding at the end of the fourth day of automaintained key pecking (mean percentage of trials with at least one response on Day 4 = 94.8%, SD = 8.6). Thus, on the following day, a discrimination contingency was introduced in which a red key light (R) was regularly followed by a food hopper presentation (+) and a green key light (G) was never followed by food (-). Each 5-sec stimulus was presented 18 times with the order of presentation of stimuli arranged according to schedules described by Fellows (1967). Briefly, each of these schedules consisted of three blocks of 12 trials, each block containing six G presentations and six R presentations. No stimulus was presented more than three times consecutively, and the number of alternations from one stimulus to the other was minimized. All animals were run on the same schedule on any given day.

On the second day of discrimination training, reinforcement of the red key light was reduced to 9 of the 18 presentations (i.e., 50% reinforcement schedule). The partial reinforcement schedule was derived in a manner similar to that of the aforementioned schedule with the additional restriction that no more than five consecutive stimulus presentations would be nonreinforced. The animals were run for a total of four days on the partial reinforcement discrimination schedule (9 R+, 9 R-, 18 G-) prior to the ethanol test phase.

Testing under ethanol occurred on alternate days over the next 12 days. Baseline sessions conducted following saline injections

were given between successive ethanol sessions. All animals were tested under the same dose of ethanol on a given test day, with the previously described automaintenance schedule in effect. The doses of ethanol used were as follows: .4 g/kg (5% v/v ethanol in normal saline), .8 g/kg (10.1% v/v ethanol) and 1.2 g/kg (15.2% v/v ethanol). All injections were given intraperitoneally in a volume of 10 ml/kg. Test doses were given first in an ascending sequence, and then in a descending sequence. Thus, each animal received each dose twice (see Table 1).

The following measures were recorded on each individual trial: number of responses during red key light-on periods (CS+ responses), number of responses during green key light-on periods (CS- responses), and number of responses occurring during the ITI. From these measures, the rate of responding during the appropriate intervals and the percentage of trials (both CS+ and CS-) with at least one response were calculated.

Phase 2: Interdimensional discrimination training. Twenty-five nonexperimental days followed the final day of dose-response testing. Throughout this period, the pigeons were maintained at 75% of their ad lib weights. Subsequently, each animal was given two additional days of discriminated red-green response training in order to re-establish a stable baseline response rate. The parameters for these trials were identical to those used in the first phase of the experiment and each bird was run following an injection of physiological saline. At the end of the second day,

Table 1. Dosing sequence during red-green discrimination testing

	Test Day	Dose (g/kg)
Ascending Sequence	1	.4
	2	0 (normal saline)
	3	.8
	4	0
	5	1.2
	6	0
Descending Sequence	7	1.2
	8	0
	9	.8
	10	0
	11	.4
	12	0

the animals were divided into two groups (n = 4/group), matched for these response measures: (a) mean total number of responses during these two sessions, (b) mean number of CS+ (red key light-on) responses during the same two sessions, (c) mean total number of responses on the second day only, and (d) mean CS+ response rate for baseline days during dose-response testing.

The two groups of animals were then run, over the next six days, on an interdimensional discrimination task. Throughout these trials, the vertical line display (0^{o} tilt) projected onto a white background served as the CS+, while the plain, white, illuminated key served as the CS-. Thus, 5-sec vertical line (CS+) exposures were consistently followed by a 5-sec period of food availability, whereas 5-sec white key (CS-) exposures were never followed by food. The timing and scheduling were similar to those in effect during the initial phase of the experiment.

On the first day of interdimensional discrimination training, one of the groups received injections of physiological saline prior to the session (Group S1) and the other group was given injections of ethanol (.8 g/kg, 10.1% v/v ethanol in normal saline, Group A1). On subsequent days, the injected solution was alternated for both groups; thus Group S1 received saline injections on odd-numbered training days and ethanol injections on even-numbered days, whereas Group A1 was injected with ethanol on odd-numbered days and saline on even-numbered training days. Both groups were therefore equated for experience with alcohol at the end of the six days of training.

On the first four days of interdimensional discrimination training, the vertical-line display was reinforced on all trials. On the final two days, a 50% reinforcement schedule was in effect. The purpose of partial reinforcement of the CS+ was to prolong responding during the extinction test phase.

Upon completion of the interdimensional discrimination training, the pigeons were reassigned to two different groups, Group Saline and Group Alcohol, matched for the following measures: (a) mean CS+ (vertical) response rate during each bird's final ethanol session, (b) mean CS+ response rate during each bird's final saline session, (c) mean CS+ response rate, regardless of solution injected, for the sixth (final) day of training, (d) mean CS+ response rate, regardless of solution injected, for the fifth day of training, (e) mean CS+ response rate, regardless of solution injected, for the first day of training, (f) mean CS- (white key) response rate, regardless of solution injected, for the first day of training, (g) mean CS+ response rate, regardless of solution injected, for the second day of training, and (h) mean CS- response rate, regardless of solution injected, for the second day of training.

Phase 3: Stimulus generalization testing. At the beginning of each of the three stimulus generalization test sessions, subjects were given eight "refresher" trials under the same stimulus and reinforcement conditions as during interdimensional discrimination training (2 vertical +, 2 vertical -, 4 white -). Generalization testing was then initiated, and was conducted in extinction (i.e.,

none of the stimuli was followed by food reinforcement). Each of the eight line orientations described earlier was presented four times per test session. The 32 stimulus presentations were arranged in four blocks, each block containing the eight different line orientations. The plain, white, illuminated key (CS-) was not presented during the test sequence. All animals received the same sequence of test stimuli on any given test day, with the sequence determined in the following manner. The order of presentation of the individual stimuli in the first block of eight trials was completely randomized. The order of stimuli in subsequent blocks of eight trials was also determined randomly, but the stipulation was added that no stimulus could appear in the same quarter of the block as it had appeared in on any previous block. Thus, over the four blocks of eight stimuli, each test stimulus appeared once in the first or second position in the block, once in the third or fourth position in the block and so on. An additional restriction was placed on the stimulus order as a means of counterbalancing directionality of the line tilt over trials. Since three of the line orientations were in a clockwise direction from 0^{o} and three were in a counterclockwise direction, it was further dictated that within each half-block of stimuli, no more than two of the stimuli could be oriented in the same general direction (clockwise or counterclockwise) from 0^{o}. Stimulus sequences for the three test sessions are presented in Table 2. As before, the ITI averaged 60 sec, with stimulus-on periods lasting for 5 sec. The number

Table 2. Stimulus sequences for generalization testing

Day 1 Block	Stimulus Number			
1	3,2	6,8	7,4	1,5
2	4,8	1,7	3,5	6,2
3	1,5	3,2	8,6	7,4
4	6,7	5,4	2,1	3,8

Day 2 Block				
1	8,3	1,2	4,5	7,6
2	4,7	6,8	2,3	5,1
3	2,6	5,3	7,1	8,4
4	5,1	4,7	8,6	2,3

Day 3 same as Day 1

Stimulus Number	Orientation
1	0^{o}
2	112.5^{o}
3	22.5^{o}
4	157.5^{o}
5	90.0^{o}
6	135.0^{o}
7	45.0^{o}
8	67.5^{o}

of key pecks during each of the stimulus-on and ITI periods was recorded.

Each of the treatment groups (Groups Alcohol and Saline) consisted of two birds from Group S1 and two from Group A1; therefore, the groups were equated with respect to history of drug exposure during training. Group Saline served as the saline-test group, and Group Alcohol as the ethanol-test group. Each animal was tested with the same solution on all three of the test days. In order to equate groups for exposure to ethanol, injections of the nontested solution were administered approximately 1 hr after the test trials. Thus, following test sessions, Group Saline was injected with ethanol and Group Alcohol with saline. The dose of ethanol used for both during- and post-test injections was .8 g/kg. This dose was chosen because in the initial phase of the experiment, it was shown to have neither facilitative nor inhibitory effects on responding during the dose-response determination.

Results

Body Weights

There were no differences in the initial weights of the pigeons assigned to the two generalization test groups [t (6) = 2.09]. A mean weight was calculated for each bird over the following phases of the experiment: (a) magazine training and autoshaping, (b) discrimination training and dose-response determination, and (c) stimulus generalization test phase. A groups x phases analysis of variance revealed no effect of groups and no groups x phases inter-

action, but the main effect of phases was reliable [F (2, 12) = 57.36, $p < .001$]. A followup analysis indicated that this difference was attributable to an average loss of 6.4 g per animal between the magazine training and autoshaping phase and dose-response testing. This was primarily due to the fact that the animals had not yet reached the 75% deprivation level at the initiation of magazine training. The group mean weight of the eight pigeons during the dose-response and generalization test phases was within .5% of 75% of their initial mean weight.

Discrimination Training and Dose-Response Determination

Throughout this phase, ITI responses never exceeded 6% of the total number of responses emitted, and CS- responses represented less than 1% of the total responses. Subsequent analyses therefore utilized only CS+ response measures in determining the effects of ethanol on responding. Nonparametric statistics were used since the homogeneity of variance assumption was violated in a number of the comparisons.

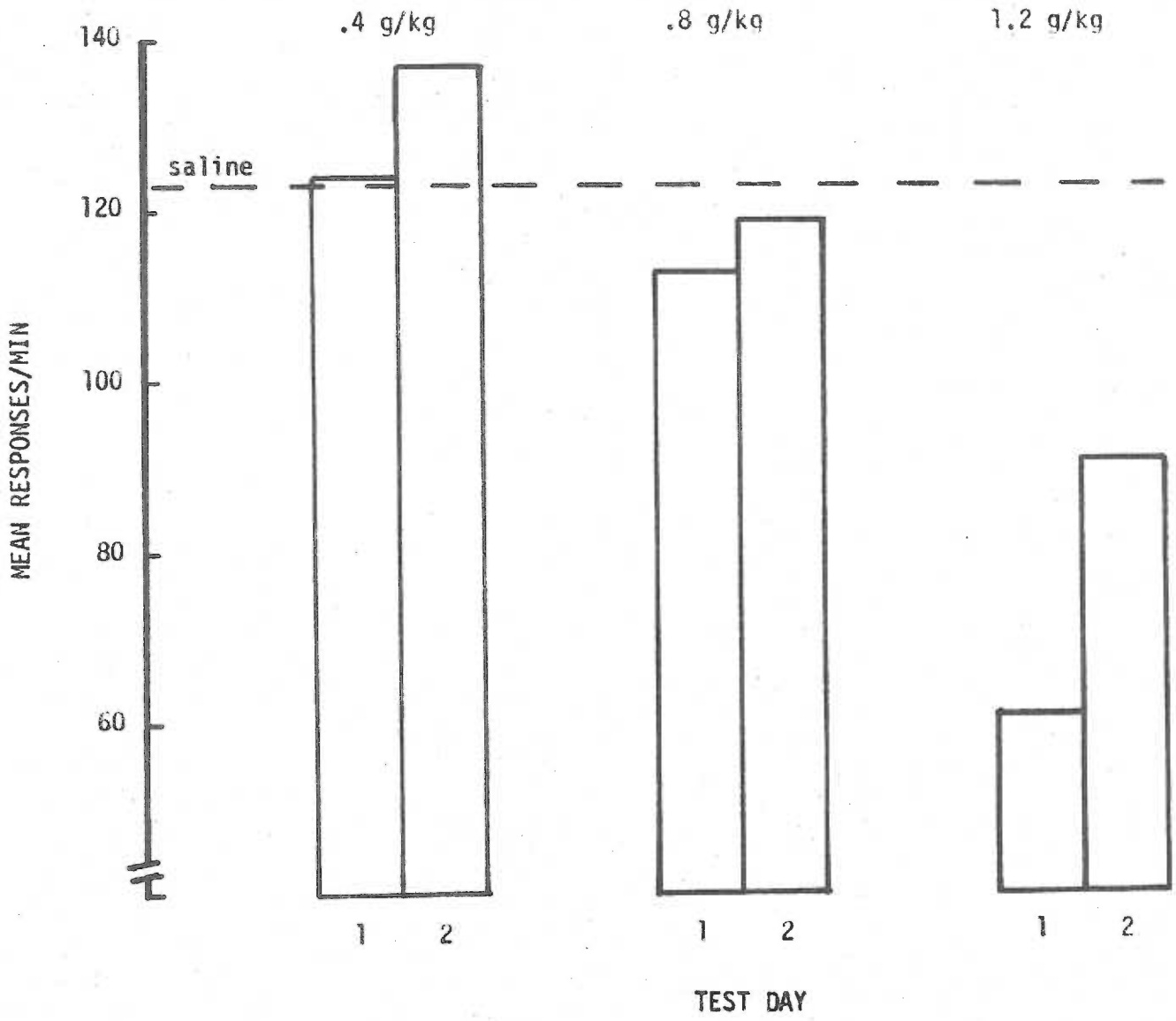
A Friedman two-way analysis of variance by ranks was performed to assess baseline response differences across saline days. Mean response rates were calculated for the baseline day prior to the first ethanol treatment and for the subsequent six intervening baseline days. There were no differences among the baseline days [Xr^2 (6) = 5.1], and thus a mean baseline score was calculated for each bird and used for subsequent comparisons.

Mean response rates for the eight pigeons on ethanol treatment

days are graphed in Figure 3, with the broken line representing the mean saline baseline response rate. "Test Day 1" refers to the animals' first exposure to each of the doses, all of which were given during the ascending sequence of this phase (concentration [doses] increasing over days). Second exposures to the same dose are represented as "Test Day 2" and took place during the descending sequence (concentration [doses] decreasing over days). It can be seen that the highest dose of ethanol (1.2 g/kg) markedly depressed response rate following its initial administration. This observation was supported statistically, with the rate of responding following administration of the highest dose significantly lower than the saline baseline rate [Wilcoxon T (8) = 0, $p < .01$]. However, the decrease in response rate for the second test under 1.2 g/kg was not statistically reliable [T (7) = 3]. The middle dose (.8 g/kg), on the other hand, had no effect on response rate on either test day, as is evident from the figure [Ts (8) $\geq$ 12.0]. Comparison of response rates following administration of the lowest dose of ethanol (.4 g/kg) to the baseline response rate resulted in contrasting findings for the two test days. Response rate during the first test under .4 g/kg of ethanol did not differ significantly from the baseline rate [T (8) = 15.5], although during the second .4-g/kg test, the pigeons responded to the stimulus at a reliably higher than baseline rate [T (8) = 1, $p < .01$].

The mean percentage of trials with at least one response rarely varied considerably from 100%, and dropped below 90% only on those

Figure 3. Mean response rate under each of the various ethanol doses is graphed. "Test Day 1" refers to the animals' first exposure to the respective dose, whereas "Test Day 2" refers to the animals' second exposure to that dose. Broken line represents mean saline baseline response rate.


.4 g/kg
.8 g/kg
1.2 g/kg
140
120
100
80
60
saline
MEAN RESPONSES/MIN
1
2
1
2
1
2
TEST DAY

days on which testing was conducted under the 1.2 g/kg dose. Statistical comparison of the percentage of alcohol trials with at least one response to the mean percentage of saline baseline trials with one or more responses demonstrated no differences at either the .4 or .8 g/kg doses. Furthermore, whereas this measure was significantly depressed on the first high dose (1.2 g/kg) test day [T (8) = 0, $p < .01$], the difference was no longer reliable by the second 1.2 g/kg test day [T (6) = 2].

Response Matching

The birds were matched for various response measures at two points in the experiment. The initial matching took place prior to interdimensional discrimination training (vertical + vs. white -) when the animals were divided into groups differing in order of exposure to ethanol and saline. The second matching was performed before generalization testing as a means of balancing test groups for previous response rates and order of drug administration. Tables 3 and 4 contain the results of the first and second matching, respectively.

Interdimensional Discrimination

Substantial responding to the CS- (white key) occurred only on the first two days of interdimensional discrimination training. Since half of the animals received alcohol on the first training day and half received saline (with the appropriate solutions alternated over subsequent days), response rates were evaluated for the possible effects of order of drug administration (alcohol first

Table 3. Group means prior to interdimensional discrimination training

Response Measure	Group S1	Group A1
1) Mean total number of responses, Phase 2, Days 1 & 2 (re-establishment of baseline responding)	230.5	232.5
2) Mean number of CS+ responses, Phase 2, Days 1 & 2	192.8	203.8
3) Mean total number of responses, Phase 2, Day 2	224.5	212.5
4) Mean CS+ response rate for saline baseline days during dose-response testing, responses/min	117.3	129.5

Table 4. Group means for interdimensional discrimination training: Matching prior to stimulus generalization testing

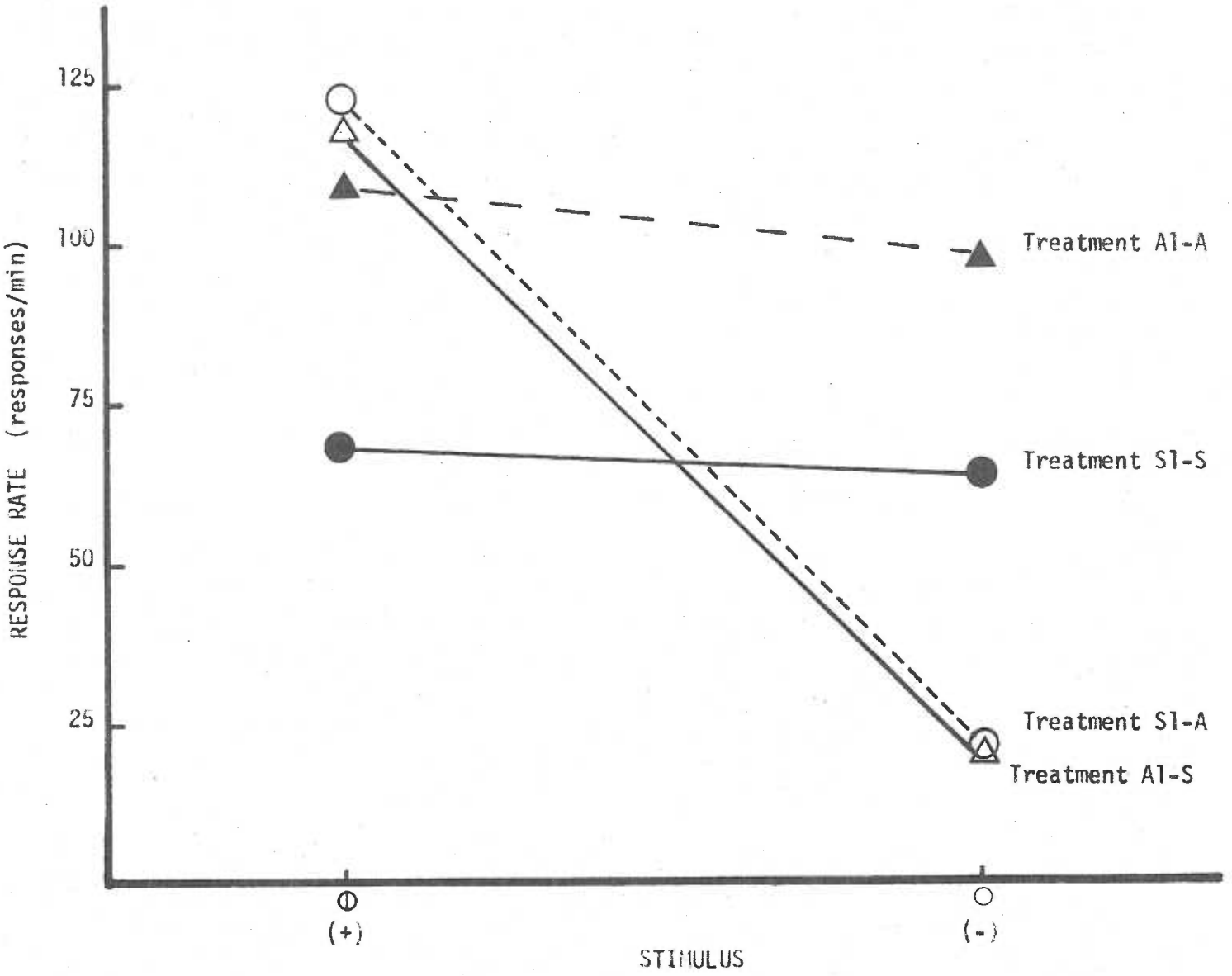
	Response Measure	Group Saline	Group Alcohol
1)	Mean CS+ (vertical) response rate during each bird's final ethanol session	136.0 responses/min	129.0 responses/min
2)	Mean CS+ response rate during each bird's final saline session	128.0	126.0
3)	Mean CS+ response rate, regardless of solution injected, sixth day of training	129.5	119.8
4)	Mean CS+ response rate, regardless of solution injected, fifth day of training	134.5	135.2
5)	Mean CS+ response rate, regardless of solution injected, first day of training	99.2	79.0
6)	Mean CS- (white key) response rate, regardless of solution injected, first day of training	89.7	72.7
7)	Mean CS+ response rate, regardless of solution injected, second day of training	131.9	108.0
8)	Mean CS- response rate, regardless of solution injected, second day of training	12.0	30.0

vs. saline first) on discrimination learning for the first two days of training.

Response rates for the two stimuli (CS+ and CS-) are plotted in Figure 4. The line labelled S1-S represents animals that received saline on the first training day while tested under saline, whereas S1-A represents the same animals while tested under alcohol. The line labelled A1-A depicts the rates of animals receiving alcohol on the initial training day and A1-S is the same group's responding under saline. Alcohol treatment is represented by the broken lines, while saline treatment is signified by solid lines. Additionally, closed symbols represent responding on the first training day, whereas open symbols represent response rates on the second day. An order x drug treatment x stimulus analysis of variance showed that there was no main effect of order [F (1, 6) = 1.17] and no drug treatment effect. The stimulus effect was reliable [F (1, 6) = 34.10, $p < .01$], with a significantly higher rate of responding occurring during CS+ presentations than during CS- presentations. The order x treatment interaction, the order x stimulus interaction and the treatment x stimulus interaction were all nonsignificant. There was a reliable order x treatment x stimulus interaction [F (1, 6) = 31.50, $p < .01$], which was attributable to superior discriminated responding by all animals on the second training day, regardless of drug treatment.

After the second day of interdimensional discrimination training, responding to the CS- was negligible, representing less than 4% of

Figure 4. Interdimensional discrimination performance: Days 1 and 2. Response rates for CS+ and CS- are plotted for the first two days of interdimensional discrimination responding. S1-S represents animals that received saline on the first training day while responding under saline, whereas S1-A represents the same animals while responding under alcohol. Line A1-A depicts the rates of animals receiving alcohol on the initial training day, and A1-S is the same group's responding under saline. Alcohol treatment is represented by broken lines, while saline treatment is represented by solid lines. Closed symbols signify responding on the first training day, whereas open symbols represent response rates on the second day.


125
100
75
50
25
RESPONSE RATE (responses/min)
Treatment A1-A
Treatment S1-S
Treatment S1-A
Treatment A1-S
(+)
(-)
STIMULUS

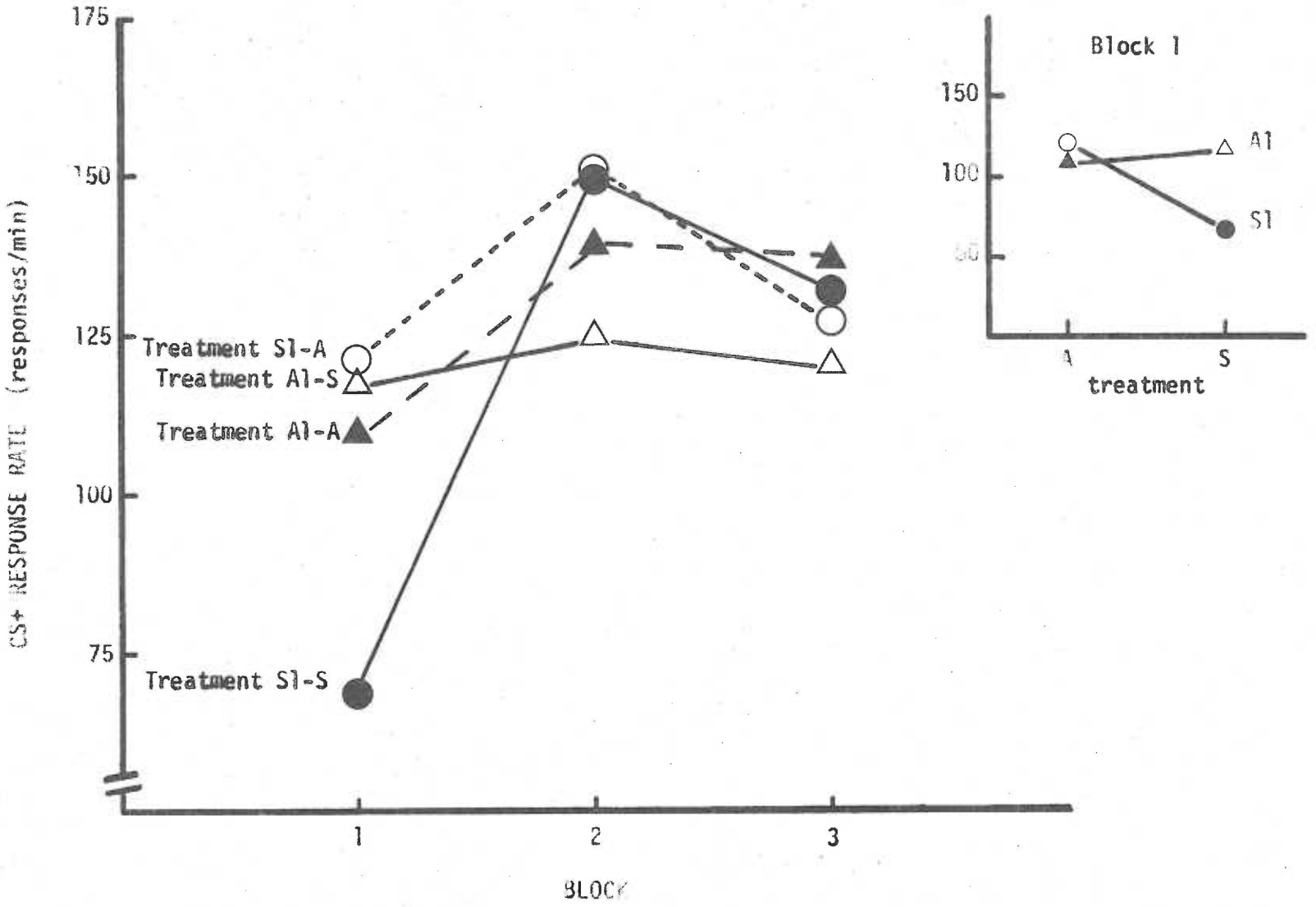
the total responding on any single day. Subsequent analyses therefore utilized only the CS+ response measure.

Figure 5 shows the effects of order of drug administration and drug treatment on response rate over blocks of days. Each block consisted of two days, with one alcohol training day and one saline training day per block for all animals. Group descriptions for this figure are identical to those used in the previous figure. Closed symbols represent responding on the first day of each block and open symbols, the second day.

An order x treatment x blocks analysis demonstrated a significant blocks effect [F (2, 12) = 8.21, $p < .01$] and a reliable order x treatment x blocks interaction [F (2, 12) = 13.17, $p < .01$]. The remaining main effects and interactions were nonsignificant. A followup analysis indicated that the blocks effect was the result of a reliable increase in response rate from the first to the second block [F (1, 6) = 14.90, $p < .01$] and a reliable decrease in response rate from the second block to the third (during which the partial reinforcement schedule was put into effect) [F (1, 6) = 7.33, $p < .05$].

Individual analyses were carried out for each block in an attempt to determine the cause of the three-way interaction. An order x treatment analysis of variance for the first block revealed no main effects of order or treatment, but there was a significant interaction involving the order and treatment factors [F (1, 6) = 10.00, $p < .05$]. Graphic interpretation of this interaction suggested

Figure 5. Effects of order of drug/no-drug administration and drug treatment on response rates over blocks of days. Symbol descriptions are identical to those used for the previous figure.


175
150
125
100
75
CS+ RESPONSE RATE (responses/min)
Treatment S1-A
Treatment A1-S
Treatment A1-A
Treatment S1-S
1
2
3
BLOCK
Block 1
150
100
A1
S1
A
S
treatment

that Group S1 showed a larger increase in responding from the first to the second training day than Group A1 (see inset to Figure 5). This appeared to be due to a higher rate of responding for Group A1 on the first day than for Group S1 (closed symbols in inset), although this difference failed to reach statistical significance. By the second day of discrimination training, response rates for the two groups were nearly identical (open symbols in inset).

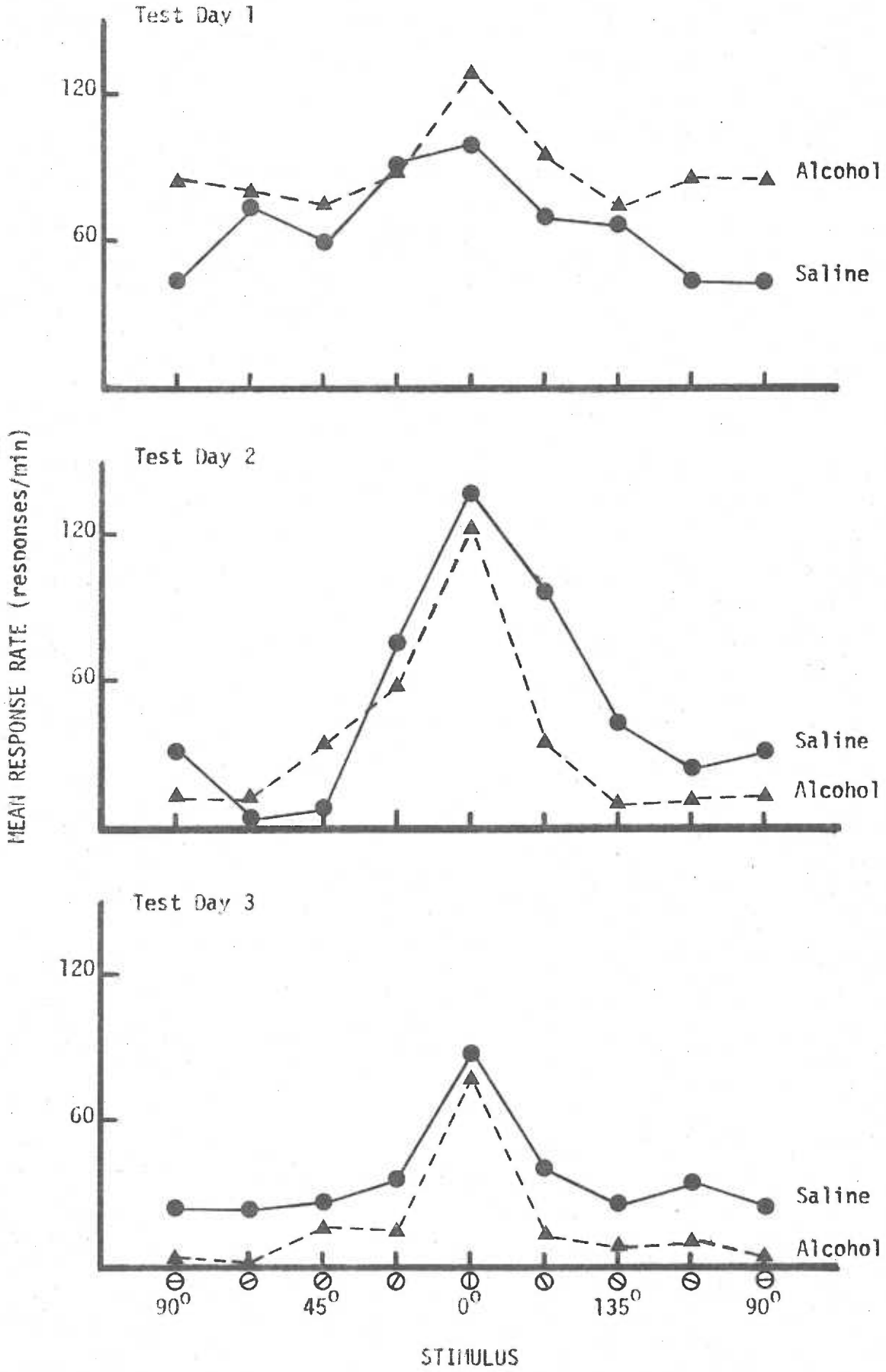
Analysis of the data from the second and third blocks disclosed no main effects of order or treatment and no order x treatment interaction in either block [*F*s (1, 6) < 3.74]. Since order of drug administration did not affect response rate in the final blocks of interdimensional discrimination training, order was not included as a factor in the interpretation of the generalization test data.

Stimulus Generalization

Response rates to the various stimuli during the three generalization tests are plotted in Figure 6. It is evident from the graphs that generalization of responding to orientations of the line other than 0^{o} (vertical) was greatest on the first test day. On subsequent days the gradients steepened, with over 57% of the total responding occurring in response to the vertical stimulus (CS+) on the final test day.

A three-way analysis of variance, with factors of treatment (alcohol vs. saline), days and test stimuli confirmed these observations. There was a significant main effect of days [*F* (2, 12) =

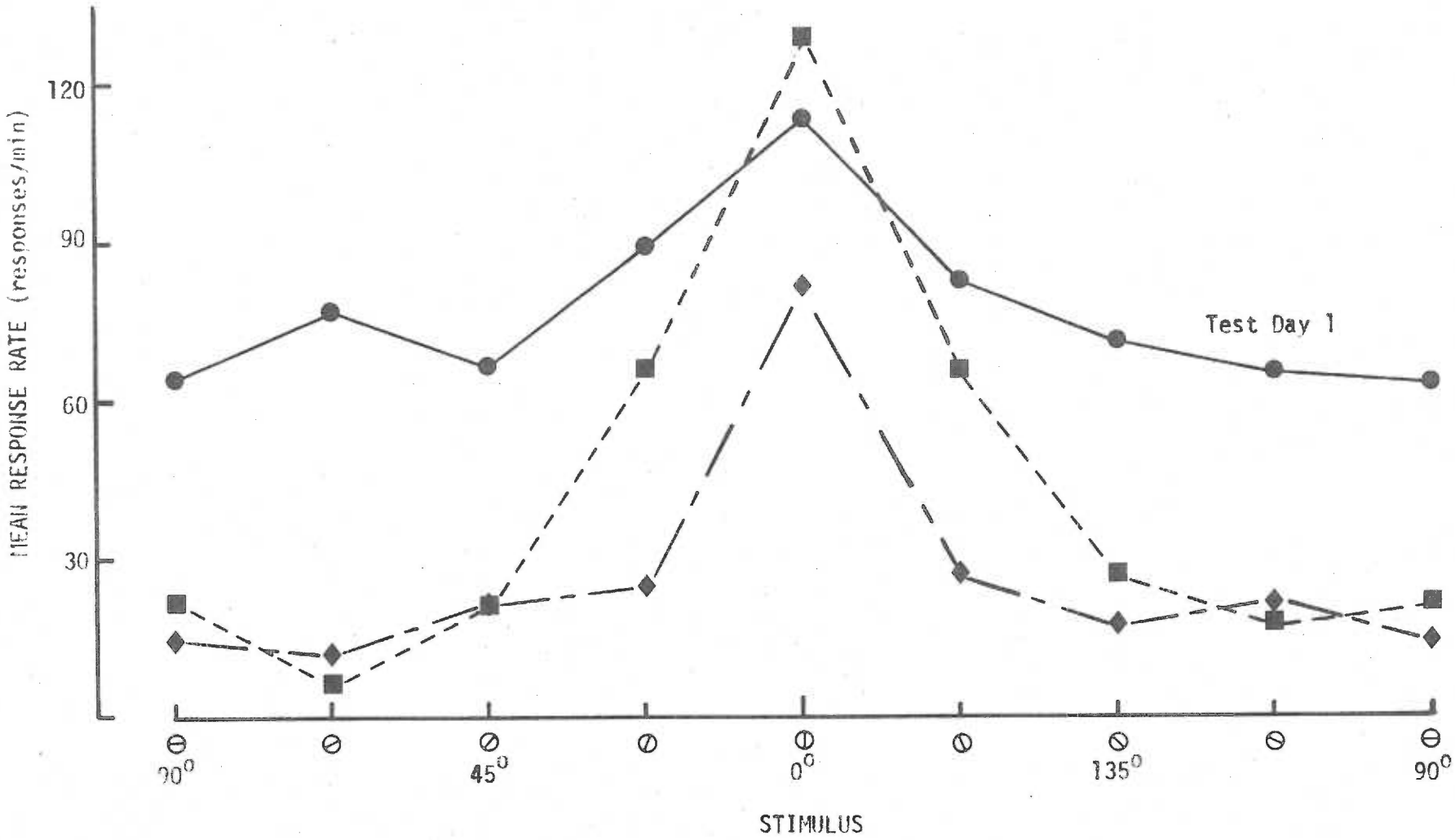
Figure 6. Response rates to the generalization test stimuli are graphed for the Alcohol and Saline groups.


Test Day 1
120
60
Alcohol
Saline
Test Day 2
120
60
Saline
Alcohol
Test Day 3
120
60
Saline
Alcohol
MEAN RESPONSE RATE (responses/min)
90°
45°
0°
135°
90°
STIMULUS

14.41, $p < .001$], a significant test stimulus effect [F (7, 42) = 18.43, $p < .001$] and a reliable days x test stimulus interaction [F (14, 84) = 4.01, $p < .001$]. The fact that there was no main effect of treatment and no treatment x test stimulus interaction suggests that alcohol affected neither overall rate of responding nor the shape of the generalization gradients. The treatment x days and treatment x days x test stimulus interactions were also nonsignificant, therefore the two treatment groups' data were pooled for followup analysis.

The main effect of days was attributable to a reliable decrease in responding from the first to the second test day [F (1, 6) = 16.16, $p < .01$], with response levels remaining unchanged from the second test day to the third. The days x test stimulus interaction is best considered by reference to Figure 7, which shows generalization gradients for the three test days, collapsed across treatment groups. Although responding to the generalized stimuli decreased markedly from the first to the second test day, the number of key pecks made in response to the CS+ remained virtually unchanged. This is reflected by a significant interaction of days with test stimuli for the first two test days [F (7, 42) = 5.64, $p < .001$]. A days x test stimulus interaction for the second and third tests suggested that the lack of change in response levels from Test Day 2 to Test Day 3 was the result of consistently low response rates to the five stimuli most remote from the CS+ on both test days, combined with a reliably decreased rate of responding to the CS+ from the second

Figure 7. Generalization gradients for the three test days, collapsed across treatment groups. Circles joined by solid lines represent responding on Test Day 1, squares connected by broken lines represent Test Day 2 responding, and diamonds symbolize responding on Test Day 3.


MEAN RESPONSE RATE (responses/min)
120
90
60
30
Test Day 1
90°
45°
0°
135°
90°
STIMULUS

to the third test [t (7) = 2.87, $p < .05$]. Reference to Figure 5 suggests that a similar decrease in response levels occurred for the two stimulus orientations closest to the CS+, although this observation was upheld statistically only for the clockwise change in orientation (22.5°) [t (7) = 3.12, $p < .05$]. Decreased responding to the CS+ combined with unchanged responding to the more extreme generalized stimuli resulted in a reliable interaction of days and test stimuli for the final two test sessions [F (7, 42) = 4.44, $p < .001$].

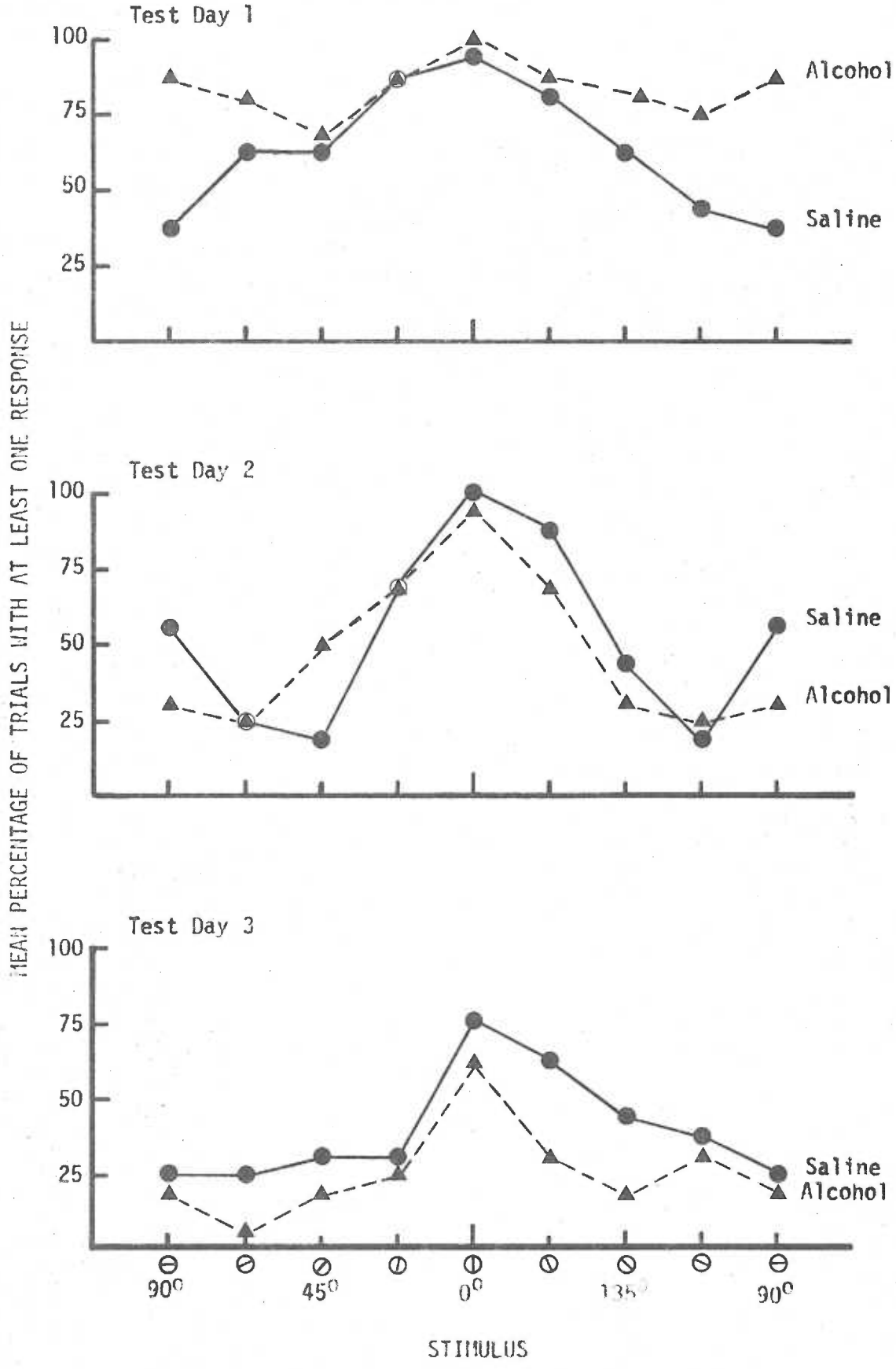
The mean percentage of trials with at least one response is plotted for the various generalization test stimuli in Figure 8. It is clear that these gradients closely resemble those of Figure 6 in which the mean response rates during the individual test stimuli are graphed. Indeed, a treatment x days x stimulus analysis of variance yielded results quite similar to the results reported for the rate measure, and the followup analyses were also directly comparable.

To reiterate, whereas responding to the various stimuli changed reliably over days, with progressively less responding to peripheral stimuli, the difference between treatment groups was negligible. Thus, ethanol, at the dose used, was found to have no effect on stimulus control of automaintained responding.

Discussion

In this experiment, stimulus generalization of autoshaped key-pecking was not altered by a dose of ethanol (.8 g/kg) which left

Figure 8. Mean percentage of trials with at least one response for various generalization test stimuli, Groups Alcohol and Saline.


Test Day 1
100
75
50
25
Alcohol
Saline
Test Day 2
100
75
50
25
Saline
Alcohol
Test Day 3
100
75
50
25
Saline
Alcohol
90°
45°
0°
135°
90°
MEAN PERCENTAGE OF TRIALS WITH AT LEAST ONE RESPONSE
STIMULUS

CS+ response rates unaffected. Additionally, a lower dose of ethanol (.4 g/kg) was found to increase reliably rate of key pecking, whereas a higher dose (1.2 g/kg) decreased key pecking during a discrimination task.

Despite publication of numerous empirical and theoretical examinations of the autoshaping phenomenon, few investigations have been reported on the effects of drugs on responding generated by this procedure. Poling and Thompson (1977) reported that d-amphetamine in doses of .5, 1.0 and 2.0 mg/kg decreased automaintained responding in a dose-dependent manner. In the present study, ethanol in a quantity of .4 g/kg was found to increase response rates during the second (but not during the first) test with this dose. This observation is generally consistent with the findings of others who have reported a stimulatory effect of ethanol at low doses (e.g., Leander et al., 1974, in pigeons; Sanders, 1976, in mice; Buckalew & Cartwright, 1968, in rats). The motor-impairing effects of higher ethanol doses have been well documented (e.g., Kalant & Czaja, 1962; Hunt & Overstreet, 1977).

That tolerance developed to the effects of ethanol on responding is suggested by the fact that the activating effects of the low dose were observed only upon its second administration and the debilitating effects of the high dose were largely attenuated by the time of its second presentation. Nevertheless, the overall dose-related effects of ethanol on automaintained responding were similar to those reported for responding on operant schedules in the pigeon

(fixed ratio, FR, and fixed interval, FI; Leander et al., 1974).

Although no effects of the drug on stimulus control were discovered in this experiment, the procedure used appears to have promise as a means for investigating stimulus control. Since response rates during generalization testing covered a range from high (to the CS+) to low (to peripheral GSs) within each test session, with response levels distributed over the entire scale, the procedure should be less susceptible to interpretational difficulties resulting from measurement or scaling problems. For example, if drug treatment had resulted in a flattened gradient, ceiling effects could have been ruled out by contrasting drug-induced changes in responding to the GSs most similar to the CS+ with changes in responding to the more peripheral GSs. Presumably, ceiling effects would cause a more dramatic flattening of the slope at the GSs in closest proximity to the CS+.

Further evaluation of ceiling effects was possible during later phases of testing in this design. Consistent with other studies of generalization (e.g., Jenkins & Harrison, 1960; Hoffman & Fleshler, 1961), repeated testing in extinction in the present experiment resulted in a progressive sharpening (increasing slope) of the generalization gradients. Additionally, by the third day of testing, responding to all stimuli (including CS+) had decreased. This lower level of responding in comparison to that occurring on the first two days of testing brought key pecking to a level considerably below the ceiling (which was presumably represented by

CS+ responding in the previous test sessions). As a result, the method includes a margin of safety in regard to possible ceiling effects.

The dose of ethanol administered during the generalization test phase was one which had been determined during the hue discrimination to leave CS+ responding unmodified, and indeed, responding to CS+ was equivalent for the groups on each of the generalization test days. The fact that a dose lower than the one used during generalization testing increased responding during the hue discrimination whereas a higher dose decreased response rates supports the assertion that the generalization test dose was potentially "behaviorally active." Nevertheless, ethanol, when administered in that dose, failed to alter stimulus control.

GENERAL DISCUSSION

The fact that ethanol was found to leave stimulus control unaffected in a stimulus generalization paradigm is especially interesting in light of studies in which ethanol was reported to alter discrimination performance (Blough, 1956; Hughes & Forney, 1961; Van Laer et al., 1965; Holloway & Wansley, 1973). There are at least two possible explanations for this difference. In each of the discrimination experiments, ethanol purportedly increased the number of "errors" made by experimental subjects. Commonly, the errors consisted of an increase in responding to a previously nonreinforced stimulus (CS-). It is notable that in the generalization procedure, none of the test stimuli had been specifically nonreinforced during training. It seems plausible then, that one interpretation for the discrepancy between generalization and discrimination experiments is that ethanol only (or predominantly) affects inhibitory control. Thus, an increase in responding to the CS- in a discrimination paradigm might reflect a disinhibition of responding by ethanol; since there were no explicitly inhibitory stimuli in the present generalization experiments, and thus no stimuli to which responding could be disinhibited, this effect of ethanol would not have been apparent.

An alternative explanation of the discrimination-generalization discrepancy is that discrimination experiments may be more prone to changes in stimulus control which are solely the result of ceiling or floor effects. In discrimination experiments in which rate of

responding to the CS+ and a single CS- are measured, response levels are generally at a maximum during CS+ presentations and at a minimum during CS-. This pattern of responding is especially susceptible to interpretational difficulties due to measurement problems. For example, in cases where CS- responding is increased while CS+ responding remains unchanged by the drug, it is difficult to ascertain whether the effects upon stimulus control are not simply explicable in terms of a drug-induced activation of responding limited by a ceiling at CS+. Generalization testing, on the other hand, permits determination of response levels at points intermediate to those at which responding is very high or very low. Drug-induced changes in response level extremes in the absence of attendant alterations in responding to intermediate stimuli suggest the possibility of ceiling or floor effects. In any case, there is considerable advantage in the ability to demonstrate that CS+ response rates have not reached the upper (or lower) limit of the subject's capabilities; by doing so, ceiling (and floor) effects can be ruled out.

The failure to find any effect of ethanol on stimulus control in the present set of experiments, and similar negative results in studies using other drugs suggests that stimulus control is, indeed, a robust phenomenon. As proposed earlier, it may be that stimulus control is only affected by doses of drug which drastically modify response levels. It has also been suggested that perceptual processes

which have fundamental survival value are only disrupted at relatively high doses of ethanol (Johnson, 1977). If stimulus control is one of these processes, as has been postulated (Key, 1961), then it may be that the stimulus control process will not be susceptible to ethanol's effects until doses are reached which also impair gross motor function. If this is the case, the difficulties involved in seperating drug effects on motor response systems from drug effects on the hypothesized "perceptual" processes of stimulus control are obvious. Under these circumstances, a drug-induced change in the slope of a generalization gradient could represent an alteration of perceptual processes, a modification of "performance variables" or a combination of both.

The proposed distinction between a drug's effect on an organism's response output and its effect on the "processing" of a stimulus is an interesting one. A number of drugs (e.g., ethanol, morphine, pentobarbital) have been shown to induce gross motor impairment at a wide range of doses. It is quite possible that in these instances, drug effects on processing would often be confounded with effects on response output. Succinct experimental interpretation would thus be limited to studies utilizing drug doses which do not severely alter baseline response output.

In contrast to those drugs which act largely on the organism's output of a response, others (e.g., delta-9-tetrahydrocannabinol and LSD) are commonly believed to exert their main effects on perceptual

processes, at least when administered in small doses (Weisz & Vardaris, 1976; Dykstra & Appel, 1972). Although much of our present knowledge about these drugs is based on anecdotal reports and limited experimentation, it is possible that this type of drug may be more likely to alter the stimulus "processing" which is believed to be the basis for stimulus control. In fact, one of the few reports of a reliable drug effect on stimulus control unconfounded by absolute response-level differences involved the use of delta-9-tetrahydrocannabinol, a proposed "perceptually active" drug (Weisz & Vardaris, 1976).

In addition to processing and output effects, it is possible that some drugs may affect sensory reception. Conceivably, the drug could act directly at the receptor, or in the case of drugs which alter "perceptual processes," the alteration might occur preferentially according to sensory modality. Thus, failure to find an effect of a theoretically "perceptually active" drug (e.g., Dykstra & Appel, 1970) may reflect the possibility that the stimulus was delivered to a sensory system which was relatively insensitive to actions of the drug.

While it is not yet possible to distinguish behaviorally among these processes, it seems plausible that a drug may affect either stimulus input, stimulus processing, memory retrieval, response output, or any combination thereof. Furthermore, it is also conceivable that some or all of these processes may be affected differentially depending upon whether the stimulus is excitatory or

inhibitory. At least two of these factors may have played a role in the present set of studies: Ethanol may exert strong effects only on inhibitory control (which was not involved in the present studies), or it may alter stimulus control only at doses which inordinately impair gross motor function.

SUMMARY AND CONCLUSIONS

Two experiments were conducted to examine the effects of a single dose of ethanol on stimulus control, as defined by the slope of stimulus generalization gradients. In the first study, ethanol's effect on the generalization of conditioned suppression to tone frequencies was studied in rats. Specifically, a tone of a given frequency was paired with shock, and the subsequent ability of that frequency (CS) and tones of other frequencies (GSs) to disrupt ongoing responding was measured. Although the slopes of the generalization gradients were unaffected by ethanol administration, a reduction in the overall amount of conditioned suppression was observed for the ethanol-treated animals on the second test day. It was concluded that a generalization decrement interpretation was the most parsimonious explanation for the latter effect.

In the second experiment, the effect of ethanol on generalization of the pigeon's autoshaped key peck was examined along a line-tilt continuum. A preliminary dose-response analysis of responding in a hue-discrimination task indicated increased CS+ responding at a low dose of ethanol (.4 g/kg) and decreased responding at a higher dose (1.2 g/kg). Generalization testing involved the use of a dose of ethanol (.8 g/kg) which had been found to leave CS+ responding unaffected during the hue-discrimination task. Following injections of ethanol or placebo, responses to each of eight stimuli were recorded. The stimuli consisted of a line orientation which had previously been paired with food reinforcement (CS+)

and seven other orientations having no history of differential reinforcement (GSs). Ethanol was found to leave stimulus control unaltered.

The results of these experiments were discussed in the light of discrimination experiments in which ethanol has been found to alter stimulus control. Scaling or measurement problems were suggested as a possible explanation for the discrepancy between the two types of studies. It was also postulated that ethanol may only affect the slope of a generalization gradient at doses which also drastically impair responding.

The concept of stimulus control was discussed in terms of the processes hypothesized to underly the behavioral phenomenon. It was proposed that drug-induced changes in stimulus control could be the result of alterations in any number of possible "processing" mechanisms, but that these are not yet separable behaviorally. Additionally, it was suggested that ethanol might only affect inhibitory control (which was not involved in the present studies), leaving excitatory control relatively unaffected.

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