Bulletin of the Psychonomic Society
1980, Vol. 15 (2), 135-138

Ethanol and stimulus generalization

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Two experiments examined stimulus generalization after injection of a dose of ethanol that did not affect motor performance (.8 g/kg). Generalization of conditioned suppression to tone frequencies was assessed in the first study with rats. In the second study, generalization of the pigeon's autoshaped keypeck was examined along a line-tilt continuum. In both experiments, ethanol had no significant effect upon the height or shape of the generalization gradient. The second experiment also contained a dose-response analysis of keypecking in a hue-discrimination task. A low dose of ethanol (.4 g/kg) increased CS+ responding, a moderate dose (.8 g/kg) had no effect, and a high dose (1.2 g/kg) depressed responding. Responding to CS− was unaffected by any dose.

Stimulus generalization procedures have been used often to investigate the effects of drugs on stimulus control. Generally speaking, the procedure is thought to be useful for analyzing an animal's sensitivity to changes in its external environment (cf. Hearst, 1964), and many drugs have been reported to alter the shape of generalization gradients. These include LSD (Dykstra & Appel, 1972), d-amphetamine (Key, 1961), scopolamine, caffeine (Hearst, 1974), and Δ^9-tetrahydrocannabinol (Weisz & Vardaris, 1976). Among the drugs that have been reported to leave stimulus generalization gradients unaffected are LSD (Key, 1961), methadone (Thompson, Glenn, Winston, & Young, 1978), meprobamate (Knopf, Worell, & Wolff, 1959), and chlorpromazine (Key, 1961). To date, the effect of ethanol on stimulus generalization has not been reported, although a number of studies have shown ethanol-induced impairment in discrimination tasks (Blough, 1956; Holloway & Wansley, 1973; Van Laer, Jarvik, & Van Laer, 1965).

The present studies were designed to investigate the effects of ethanol on stimulus generalization gradients along auditory and visual dimensions. The ethanol dose level used in each study was chosen because it did not grievously incapacitate the animals. Although the range of possible drug effects is necessarily limited by this approach, it was thought that this strategy would make it possible to avoid the problem of interpreting drug-induced differences in generalization gradients that might be obscured by, or confounded with, differences in response levels (e.g., ceiling or floor effects).

This research was supported in part by a departmental training grant (AA07074) and by a research grant (AA01229) to Judson S. Brown from the National Institute on Alcohol Abuse and Alcoholism. J. G. Mansfield is thanked for his comments on these studies. Reprint requests should be addressed to either author at the Department of Medical Psychology, University of Oregon Health Sciences Center, Portland, Oregon 97201.

EXPERIMENT 1

The conditioned suppression technique has been used successfully to study generalization (Desiderato, 1964) and may be particularly useful for examining drug effects, since it is possible to evaluate the drug's influences upon a baseline response measure both in the presence and absence of a stimulus along the generalization continuum under study. The present experiment involved three phases: variable-interval (VI) barpress training, fear conditioning, and generalization testing. The dose of ethanol used during testing (.8 g/kg) was selected because it had been found in pilot work to cause little disruption of the leverpress response, yet is within a range that has been reported to exert reliable behavioral effects in a number of experimental situations (e.g., approach-avoidance conflict, Freed, 1967; discriminated leverpressing, Holloway & Wansley, 1973).

Method

Subjects. The subjects were 24 naive female albino rats, weighing 200-250 g. Daily food intake was restricted to maintain each rat at 80% of its initial ad-lib body weight. Free access to water was provided in the home cage throughout the experiment.

Apparatus. Four operant chambers (22.5 x 23.0 x 19.0 cm, inside) housed within separate, ventilated, sound-attenuating chambers were used. During the VI training and testing phases, the grid floors were covered by 1/8-in. Masonite. Food pellets were delivered to a food cup centered at the bottom of one end wall. A lever was mounted to the left of the food cup, 2.5 cm above the grid floor. Illumination was provided by a 28-V dc, 6-W lamp during VI training and testing, but this was reduced during fear conditioning by placing a 50-ohm resistor in series with the lamp. Additional apparatus modifications were made during conditioning: The Masonite floor was removed to expose the grid, and the rat lever and food cup were covered.

Tones of 3, 5, or 8 kHz could be delivered to speakers in each chamber, adjusted to 75 ± 3 dB against a background noise level of 64 ± 2 dB (re: 20 $\mu N/m^2$). The unconditioned stimulus (US) was a 1.3-mA shock delivered to the grid of each chamber by a relay sequence scrambler.

Procedure. On Day 1 of the experiment, each rat was individ-

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ually trained to press the lever for food reward. For the next four sessions (Days 2-5), the animals earned 100 reinforcements daily on a VI 1.5-min schedule. On Day 5, each of the three 30-sec tones (3, 5, or 8 kHz) was presented five times in random order at an intertrial interval (ITI) of 9.5 min. This was intended to adapt the animals to tone presentations.

Fear conditioning took place on Days 6-8. A delay conditioning procedure was used in which the conditioned stimulus (CS), a 30-sec tone, coterminated with a 1-sec shock US. Each session consisted of 12 CS-US pairings interspersed with four CS-alone trials at an ITI of 8 min. For half of the animals the 3-kHz tone served as the CS; the 8-kHz tone served for the remaining half. On the day after the final conditioning session (Day 9), the original VI training conditions were reinstated, and the animals were given another VI session.

Throughout both VI training and fear conditioning (Days 2-9), each animal was given an intraperitoneal (i.p.) injection of ethanol (.8 g/kg 14.2% v/v in normal saline) or an equivalent volume of saline 1.5 h after each experimental session. Injected solutions were alternated daily, with half of the animals receiving either solution on a given day. These injections were intended to acclimate the animals to ethanol's intoxicating effects, thus reducing any primary aversive properties that might be attributed to its novelty (cf. Amit & Baum, 1970).

For generalization testing, the animals were randomly divided into two groups (n = 12/group), alcohol test or saline test. Test sessions began immediately after an injection of the appropriate solution (ethanol at .8 g/kg or normal saline, i.p.). Animals were tested under the same drug conditions on each of 2 test days, and apparatus conditions were the same as they had been during VI training. Each tone frequency was presented once per session, with the order of tone presentation counterbalanced across subjects within each of the groups. The ITI was 12.5 min.

The number of leverpresses was recorded during each stimulus presentation and during the 30 sec before each stimulus presentation. A suppression ratio was 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 prestimulus interval. Approximately 1.5 h after being returned to their home cages on Test Day 1, all animals were injected with the nontested solution, thus equating them for experience with ethanol prior to each test session.

Results and Discussion

There were no differences between the groups trained with the 3-or 8-kHz tones; consequently, they were pooled for subsequent statistical analysis. The tone that had been paired with shock was designated as the CS, with the remaining tones assuming the status of generalized stimuli (GS1 or GS2 in order of proximity of the tone's frequency to that of the CS). Statistical analysis also disclosed no difference between groups in response rate during the prestimulus interval.

Suppression ratios obtained during generalization testing are listed in Table 1. As can be seen, a gradient of response strength was evident on both test days, with the greatest amount of suppression occurring during CS and the least amount during GS2. This observation was supported statistically by a three-way analysis of variance in which a significant effect of test tone [$F(2,44) = 19.32$, $p < .001$] was exhibited. The days effect was also reliable [$F(1,22) = 69.29$, $p < .001$]. However, there was no difference between the saline and ethanol groups, and none of the interactions involving drug treatment was significant.

Table 1
Mean Suppression Ratios During Generalization Testing (Experiment 1)

	Day 1			Day 2		
Group	CS	GS_1	GS_2	CS	GS_1	GS_2
Alcohol	.07	.07	.14	.26	.27	.42
Saline	.02	.05	.16	.12	.18	.35

Thus, auditory generalization gradients were unaffected by a .8-g/kg dose of ethanol in a conditioned suppression paradigm. It is possible that this dose was simply too small to exert an effect on stimulus generalization. Alternatively, in light of the fact that the same dose has been reported by others to affect various behavioral parameters in rats (e.g., Freed, 1967), it may be that certain aspects of the present experiment rendered it less sensitive to ethanol-induced differences in stimulus control. One possibility is that ethanol exerts less of an influence on stimuli presented in the auditory modality (cf. Cunningham, 1979).

EXPERIMENT 2

In this experiment, generalized autoshaped key-pecking to visual stimuli was studied in pigeons injected with alcohol or a placebo. Since alcohol has been reported to exert both response-enhancing and motor-impairing effects in pigeons (Leander, McMillan, & Ellis, 1976), an attempt was made first to determine a dose that would leave CS response rates relatively unaffected. Accordingly, a dose-response assessment was carried out while the birds were performing on a hue-discrimination problem. After the dose-response study, the birds were trained on an interdimensional discrimination task and then given 3 days of generalization testing following injections of alcohol or saline.

Method

Subjects. The subjects were eight naive domestic pigeons about 7-9 months old, weighing 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.

Apparatus. A keypecking panel was mounted on one end of a ventilated enclosure (33.0 x 33.0 x 36.0 cm), and a food hopper delivered grain through an aperture located in the center of the panel, 6.0 cm above the floor. A frosted BRS/LVE response key was situated 23.5 cm above the floor, 3.0 cm to the left of the food hopper. A miniprojector displayed one of eight different orientations of line tilts, or white, green, or red lighting onto the key (BRS/LVE Film Pattern 715). Proceeding clockwise from vertical, the orientations of the lines were: 0, 22.5, 45.0, 67.5, 90.0, 112.5, 135, and 157.5 deg. A houselight was constantly illuminated except during the operation of the food hopper.

Procedure. After four 30-min sessions of magazine training, an autoshaping procedure was used to initiate and maintain responding to the lighted key. Specifically, a red light was projected onto the key for 5 sec, after which the food magazine was activated for 5 sec. A total of 36 trials was given on each of 4 days, with a variable ITI of 60 sec (± 30 sec). On each of these training days, and on all subsequent no-drug days, the birds were

injected with 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.

Discrimination training and dose-response determination. On the 5th experimental day, a discrimination contingency was introduced in which the red light was regularly followed by food and a green light was never followed by food. Each stimulus was presented 18 times according to a predetermined schedule. On Day 2 of discrimination training, reinforcement of the red key light was given only on 9 of the 18 presentations. The animals were run for a total of 4 days on this schedule prior to the ethanol test.

Testing under ethanol occurred on alternate days over the next 12 days, and 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 discrimination 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). Test doses were given first in an ascending sequence over days and then in a descending sequence.

Interdimensional discrimination training and stimulus generalization testing. Over the next 6 experimental days, the birds were run on an interdimensional discrimination task in which a vertical line display (0-deg tilt) projected onto a white background served as CS+, while a white key served as CS−. Each stimulus was presented 18 times/session. On the first 4 days, the vertical line display was reinforced on all trials, whereas on the final 2 days, a 50% reinforcement schedule was in effect.

On any given day of interdimensional discrimination training, half of the pigeons received ethanol injections (.8 g/kg), and the other half an equivalent volume of saline, with the injected substance alternated over the 6 days of training. The birds were then assigned to two groups, Saline or Alcohol, matched for response levels during the earlier phases of the experiment.

Stimulus generalization testing took place over the next 3 days. Each of the three test sessions began with eight "refresher" trials under the same stimulus and reinforcement conditions as during interdimensional discrimination training. Subsequent generalization testing was conducted in extinction. Each of the eight line orientations was presented 4 times/session, in a counterbalanced order. The ITI averaged 60 sec.

Each animal was tested with the same injection solution on all 3 of the test days. Group Saline received injections of physiological saline 5 min prior to test sessions, whereas Group Alcohol received injections of ethanol (.8 g/kg). In order to equate groups for exposure to ethanol, injections of the nontested solution were administered approximately 1 h after the test session.

Results and Discussion

Discrimination training and dose-response determination. Throughout this phase, CS− responses represented less than 1% of the total responses in any single session. Subsequent analyses therefore utilized only CS+ response measures in determining the effects of ethanol. Nonparametric statistics were used to analyze data from this phase, since the homogeneity of variance assumption was violated in a number of the comparisons.

A Friedman two-way analysis of variance by ranks indicated no differences among mean response rates on saline days [$\chi_r^2(6) = 5.1$], and thus a mean score was calculated for each bird for subsequent comparisons (overall saline mean = 123 responses/min).

The mean response rates for each of the ethanol test sessions were compared with the saline baseline rate using Wilcoxon's matched-pairs signed-ranks test. The highest dose of ethanol (1.2 g/kg) depressed the CS+ response rate following its initial administration [mean = 61 responses/min; $T(8) = 0$, $p < .01$], although the decrease in response rate for the second test under 1.2 g/kg failed to reach statistical significance [mean = 91 responses/min; $T(7) = 3$]. The middle dose (.8g/kg) had no effect on response rate on either test day (means for the first and second tests = 113 and 119 responses/min, respectively). Response rate during the first test with .4 g/kg of ethanol did not differ significantly from the saline rate (mean = 124 responses/min), but during the second .4-g/kg test the pigeons responded at a reliably higher rate [mean = 137 responses/min; $T(8) = 1$, $p < .01$].

Stimulus generalization. Response rates to the various stimuli on each of the 3 generalization test days are plotted in Figure 1. It can be seen that generalization of responding to orientations of the lines other than 0 deg (vertical) was greatest on Test Day 1. On subsequent days, the gradients steepened, with over 57% of the total responding occurring in response to the 0 deg stimulus (CS+) on the final test day. These observations were supported statistically by a reliable effect of stimuli [$F(2,12) = 14.41$, $p < .001$], and a significant interaction of days with stimuli [$F(14,84) = 4.01$, $p < .001$]. The analysis disclosed no effect of drug

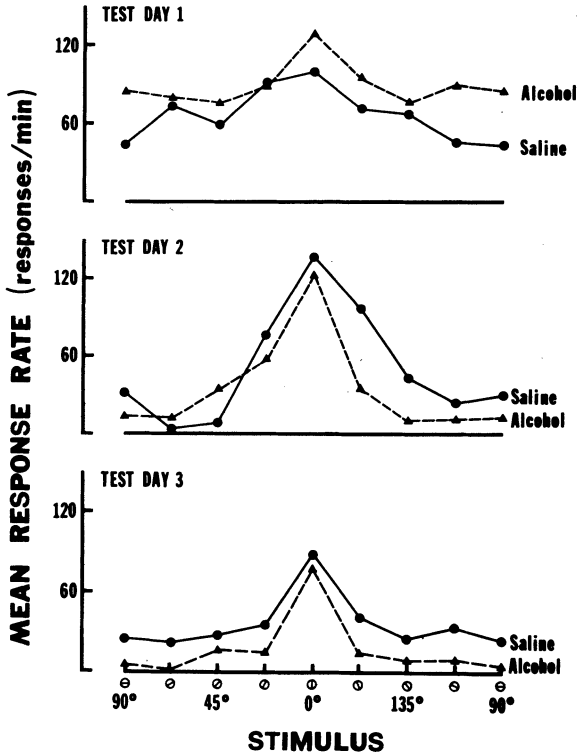

Figure 1. Mean response rate during the CS (0 deg) and the generalized line-tilt stimuli for the alcohol- (.8 g/kg) and saline-treated pigeons on each of the 3 test days.

treatment and no interaction involving the treatment factor. Thus, ethanol in a dose of .8 g/kg affected neither the overall rate of responding nor the shape of the generalization gradient.

GENERAL DISCUSSION

In separate experiments auditory generalization gradients in rats and line-tilt generalization gradients in pigeons were found to be unaltered by ethanol at .8 g/kg. Additionally, in the second experiment a lower dose of ethanol (.4 g/kg) was found to increase the rate of CS keypecking during a discrimination task, whereas a higher dose (1.2 g/kg) decreased CS+ responding. None of the doses, however, affected the number of responses to a CS−.

The fact that ethanol left stimulus control unaffected in a stimulus generalization paradigm is especially interesting, in light of the numerous studies in which ethanol has been reported to alter discrimination performance (Blough, 1956; Holloway & Wansley, 1973; Hughes & Forney, 1961; Van Laer et al., 1965). A possible explanation for this discrepancy is suggested by one major difference between the discrimination and generalization procedures involved. In the discrimination experiments cited above, ethanol was reported to increase the number of "errors" made by experimental subjects, commonly by increasing responding to a previously nonreinforced stimulus (CS−). In the generalization studies reported here, however, none of the test stimuli had been specifically nonreinforced during training. Thus, one explanation for the discrepancy between generalization and discrimination experiments might be that ethanol predominantly affects inhibitory control. An increase in responding to CS− in a discrimination paradigm might reflect a disinhibition of responding by ethanol (cf. Blough, 1956). Since there were no explicit inhibitory stimuli in the present generalization experiments, and therefore no stimuli to which responding could be disinhibited, this effect would not have been apparent.

An explanation in terms of disinhibition of CS− responding cannot, however, account for those instances in which discrimination is altered by an increase or a decrease in responding to the CS+ (e.g., Van Laer et al., 1965). For example, in the second experiment reported here, ethanol was found to increase, decrease, or not affect responding to a CS+, depending upon dosage administered, but in no case was CS− responding affected by ethanol. Obviously, this type of outcome is not readily explained by appeals to changes in inhibitory control.

Finally, a somewhat less elaborate explanation of the present outcome is plausible. It is possible that doses of ethanol that do not seriously impair responding also do not generally affect the shape of stimulus generalization gradients. If this were the case, interpretation of changes in generalization gradients would likely be obscured by the overall reduction in responding that occurs at higher doses. In the present studies, however, no effect would be expected, since the dose of ethanol was specifically chosen for its tendency to leave response rates to CS+ unaffected.

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(Received for publication November 6, 1979.)