The effects of Δ^9 -THC on wavelength generalization in the pigeon

WILLIAM D. KLIPEC

Drake University, Des Moines, Iowa 50311

FAREN R. AKINS

NASA-Ames, Mountain View, California 94035

and

ANNE KOERNER

University of Arizona, Tucson, Arizona 85721

Three groups of four pigeons were trained on a discrimination between two wavelength stimuli and tested for generalization along the wavelength dimension, once following an injection of THC and once following an injection of the Tween-saline vehicle (placebo). The results of the generalization test show a dose-dependent reduction in the area shift with no elimination of the peak shift and no effects on responding to S-. The results suggest that the effects of THC may not be related to an action of the drug on inhibitory control by S-.

Chlorpromazine (CPZ) has been found to produce a dose-dependent elimination of the peak shift and reduction of the area shift along the dimension of floor position in rats (Lyons, Klipec, & Eirick, 1973) and angularity in pigeons (Lyons, Klipec, & Steinsultz, 1973). In both of these experiments, the authors concluded that CPZ reduced the peak shift by reducing the inhibition associated with S- (the nonreinforced stimulus). This interpretation of the action of CPZ was based on earlier work by Terrace (1963, 1972). Terrace (1963) found that CPZ (and imipramine) produced a dose-dependent breakdown in discrimination performance (i.e., an increase in responding to S-) for error but not for errorless subjects. Based on this and much subsequent work, Terrace (1972) suggested that inhibition produced by a history of response rate reduction is a necessary and sufficient condition for the occurrence of behavioral contrast and the peak shift (see Purtle, 1973, or Rilling, 1977, for a review of this literature).

In a related experiment, Lyons, Ferraro, Lyons, Sullivan, and Downey (1973) reported that trans- Δ^9 -tetrahydrocannabinol (THC) produced a dose-dependent enhancement of the peak shift and area shift along the dimension of floor position in rats. The authors related this finding to the earlier CPZ research by suggesting that THC enhanced the peak shift

by enhancing the aversiveness of S-. One paradox noted in all three drug studies by Lyons and his co-workers was the absence of any effect of the drugs either on discrimination performance during the warm-up procedure before generalization testing or on S- during generalization testing. If inhibition was reduced by CPZ and enhanced by THC, direct evidence of the effects of the drugs on S- during generalization testing would have been expected.

The purpose of the present experiment was to investigate the generality of the finding that THC enhances the peak shift by replicating the Lyons, Ferraro, Lyons, Sullivan, and Downey (1973) experiment using a different species (pigeons) and stimulus dimension (wavelength) for discrimination training and generalization testing.

METHOD

Subjects

Twelve experimentally naive homing pigeons were used as subjects in this experiment. Upon arrival at the laboratory, all subjects were individually housed and provided with free access to grit, water, and mixed grain. After attaining a stable free-feeding weight, all subjects were reduced, by restricted feeding, to and run at 70%-75% of their free-feeding weights.

Apparatus

All training and testing was conducted in two Grason-Stadler (1100PB) pigeon chambers. The pecking keys were transilluminated by Industrial Electronics Engineers in-line display cells equipped with five Kodak Wrattan filters. Nine color stimuli were generated using the color mixing procedure (Lyons & Klipec, 1971). All programming and recording was accomplished with Grason-Stadler 1200 series solid state logic. A continuously present white noise was generated with a Grason-Stadler white-noise generator.

This research was conducted while the senior author was an NIH predoctoral research fellow at the University of Arizona. The THC was from batch No. SCC 75518 supplied by the National Institute of Mental Health. Research was conducted in the laboratory of Dr. Joseph E. Lyons.

Procedure

During Session 1, all pigeons were magazine and keypeck trained by successive approximations and allowed to earn 50 continuous reinforcements (CRF). A reinforcement consisted of 3-sec access to mixed grain. During this session, both the houselight and pecking key were continuously illuminated and a 555-nm light (S+) was the stimulus on the key. In Sessions 2 and 3, each subject was allowed to earn 50 CRF with S+ on the key. During Sessions 2 and 3 and all subsequent sessions, each stimulus period consisted of a 50-sec on period during which the houselight and key light were on and a 10-sec blackout of the house and key lights during which all chamber functions were inoperative. In Session 4, a random alternation of 8 S+ and 7 S- (538-nm) periods was introduced. Both stimuli were correlated with a variable interval (VI) 15-sec schedule of reinforcement (i.e., *mult* VI 15 sec VI 15 sec). Session 5 was identical to Session 4 except that the reinforcement schedule was changed to *mult* VI 30 sec VI 30 sec. Session 6 and all subsequent sessions had a duration of 30 min with a random alternation of 15 S+ and 15 S- periods.

From Session 6 to Session 16, responding was maintained on a *mult* VI 1-min VI 1-min schedule of reinforcement. In Session 17, discrimination training was introduced by correlating S- with extinction on a *mult* VI 1-min EXT reinforcement schedule. This training continued until the subject met a criterion of 10 responses to S+ for each response in the presence of S- for two consecutive sessions.

The 12 subjects were randomly assigned to one of three dosage groups (.025, .050, and .075 mg/kg THC), with 4 subjects in each group. On the day after reaching criterion, each subject was tested for generalization, in extinction, to nine different wavelength stimuli (501, 511, 538, 548, 555, 566, 576, 589, and 606 nm), including S+ and S-. Each generalization test was preceded by a 5-min warm-up consisting of an alternation of three S+ and two S- periods with the *mult* VI 1-min EXT schedule in effect.

The THC-injection solutions were prepared by removing the ethanol from the THC and placing the THC resin in a hypercolloidal suspension in a 10% Tween-isotonic saline vehicle. Injection volume was held constant across doses by preparing separate solutions of .025, .050, and .075 mg/ml. The THC solutions were kept refrigerated in amber glass vials between injections. All injections were administered in the pectoral muscles 2 h prior to generalization testing.

Each subject was tested for generalization twice: once following the administration of .025, .050, or .075 mg/kg THC, depending on the group, and once following the administration of a placebo injection of the 10% Tween-isotonic saline vehicle (Tween). Half of the subjects in each group were tested with THC first and Tween second; the order was reversed for the remaining subjects. After the first generalization test, each subject received a 48-h rest period and was then retrained to criterion before the second generalization test.

RESULTS

The mean number of total responses emitted during the nondrug tests was 622, 785, and 665, respectively, for the .025-, .050- and .075-mg/kg groups. During drug tests, the mean number of total responses increased to 682 for the .025-mg/kg group and decreased to 496 and 438, respectively, for the .050- and .075-mg/kg groups. While these changes in total responding under drug conditions were not significant, the lack of significance was most likely due to the small number of subjects and the variability introduced by counterbalancing drug and nondrug tests.

The total responses emitted to each of the test stimuli was computed for each bird. Inspection of these absolute gradients showed that all four subjects in the .025-mg/kg group exhibited peak shifts on both the drug and nondrug tests. For the .050- and .075-mg/kg groups, three of the four subjects in each group exhibited peak shifts on both tests, with the remaining subject in each group failing to show a peak shift on either test. From these data, it was evident that the drug had no effect on the peak shift per se, but further inspection of the gradients revealed an apparent decrease in the area shift at the higher doses of THC.

The mean relative gradients were constructed for the THC and Tween tests for each of the three dose conditions. These gradients are presented in Figure 1. Inspection of these gradients across the three doses of THC shows the absence of any effect of the drug on the peak shift, the apparent decrease in the area shift, and the increase in responding to S+ in the drug tests relative to the nondrug tests. To assess the reliability and dose dependency of these differences, the gradient was divided into the following three regions: the S- area (the 501-, 511-, 538-, and 548-nm stimuli), S+ (the 555-nm stimulus), and S+ area (the 566-, 576-, 589-, and 606-nm stimuli). The mean percent of total responses to each of these regions for the Tween and THC tests was computed.

As an index of change, the percent of total responses during the Tween test was subtracted from the percent of total responses during the drug test for each subject in each of three regions. Thus, a positive change would indicate an increase in responding for that region as a function of THC while a negative change would indicate a decrease.

The mean percent change in responding for each of the three dosage groups in each of the three regions of the gradient are presented in Figure 2. It is apparent in Figure 2 that the drug had no effect on responding in the area of the gradient surrounding S-. A 2 by 3 analysis of variance with simple main effects tests for THC dosage on S+ and THC dosage on the S+ area (area shift) revealed a significant increase in

Figure 1. Mean relative generalization gradients obtained following intradimensional discrimination training for three groups of four subjects tested once with a Tween placebo and once with one of three doses of THC.

Figure 2. A graph presenting the change in mean percent of total responses in three regions of the generalization gradient. The S- area represents all stimuli of the S- side of the gradient, while the S+ area represents all stimuli in the area beyond S+ away from S-. Data points represent the difference between the mean percent of total responses in an area in the drug test minus the nondrug test for each of the dose levels.

responding to S+ [$F(1,17) = 4.23$, $p < .05$] and a significant decrease in responding to the S+ area [$F(1,17) = 3.66$, $p < .05$] as a function of THC dosage.

DISCUSSION

The absence of any effect of THC on control by S- is consistent with previous findings. The significant increase in control by S+ and the decrease in the area shift are opposite to the results obtained by Lyons, Ferraro, Lyons, Sullivan, and Downey (1973). The failure to replicate the effect of THC on responding to S+ and the area shift could have been due to a number of procedural differences between the two experiments. The two studies differed in species, dosage, stimulus modality, and route of administration of the drug. Although the present data question the generality of the finding that THC enhances the peak shift and area shift, further research is clearly needed to delineate the conditions under which THC will enhance or reduce the area shift.

Despite the pharmacological dissimilarities between CPZ and THC, the drugs seem to have in common

the ability to affect the peak shift and area shift. While the previous studies have related this effect to a presumed action of the drugs on inhibitory stimulus control, there seems to be sufficient evidence to question that conclusion. In neither the present experiment nor the previous research has there been any direct evidence of an effect of either CPZ or THC on inhibitory control by S- during generalization testing. Moreover, Marriott and Ferraro (Note 1), using the same dosage, route of administration, and species as the present experiment, reported that THC had no effect on the slope of the inhibitory gradient along the line tilt dimension in pigeons.

Since the peak shift is thought to result from the interaction of inhibitory and excitatory stimulus control, a more direct analysis of the effects of both CPZ and THC on inhibitory and excitatory generalization is clearly needed before conclusions can be drawn about the way in which the drugs affect the peak shift. The need for additional work investigating the generality of the effects of THC on the peak shift is obvious. Since neither the nature of the actions of these drugs nor the process underlying the peak shift is clearly understood, conclusions relating the effects of the drugs to actions on inhibitory control would seem best viewed as tenuous.

REFERENCE NOTES

1. Marriott, R. G., & Ferraro, D. P. *The effects of THC on inhibitory stimulus control in pigeons*. Presented at the Southwestern Psychological Association meetings, El Paso, 1974.

REFERENCES

- LYONS, J., FERRARO, D. P., LYONS, J. E., SULLIVAN, J. G., & DOWNEY, D. Effects of Δ^9 -tetrahydrocannabinol on stimulus control. *Bulletin of the Psychonomic Society*, 1973, **2**, 302-304.
- LYONS, J., & KLIPEC, W. D. Color mixing with Kodak Wrattan filters. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 232.
- LYONS, J., KLIPEC, W. D., & EIRICK, R. The effect of chlorpromazine on the peak shift in the albino rat. *Physiological Psychology*, 1973, **1**, 165-168.
- LYONS, J., KLIPEC, W. D., & STEINSULTZ, G. The effect of chlorpromazine on discrimination performance and the peak shift. *Physiological Psychology*, 1973, **1**, 121-124.
- PURTLE, R. B. Peak shift: A review. *Psychological Bulletin*, 1973, **80**, 408-421.
- RILLING, M. Stimulus control and inhibitory processes. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- TERRACE, H. S. Errorless discrimination learning in the pigeon: Effects of chlorpromazine and imipramine. *Science*, 1963, **140**, 318-319.
- TERRACE, H. S. By-products of discrimination learning. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 5). New York: Academic Press, 1972.