Psychopharmacologia (Berl.) 15, 1—8 (1969)

Original Investigations · Originalarbeiten · Travaux originaux

Effects of Cannabis Sativa and Lysergic Acid Diethylamide on a Visual Discrimination Task in Pigeons *

RONALD K. SIEGEL

Department of Psychology, Dalhousie University, Halifax, Nova Scotia

Received September 3, 1968
Final Version: December 12, 1968

Summary. Four pigeons were trained on a visual discrimination task which required conditional responding along the independent dimensions of form and color. High doses of Cannabis sativa (marihuana) extract and lysergic acid diethylamide (LSD), which were equated on the basis of their effectiveness in suppressing responding, increased responding on a color dimension but not on a form dimension. High doses of LSD produced a decrement in discrimination performance while comparable doses of Cannabis did not effect accuracy. Treatment with Bromolysergic acid diethylamide, saline, and pentobarbital did not produce significant changes in performance. Results are discussed in terms of a break-down in stimulus control and central hallucinogenic activity.

Key-Words: Cannabis (Marihuana) — Lysergic Acid Diethylamide — Hallucinogens (Psychopharmacology) — Visual Perception — Psychopharmacology.

Introduction

Recently there has been much concern with the effects of hallucinogenic agents on visual discriminations. Typically, low doses of lysergic acid diethylamide (LSD: 20—300 μg/kg) improve the accuracy of some visual discriminations (BLOUGH, 1957a; BERRYMAN, JARVIK, and NEVIN, 1962; BECKER, APPEL, and FREEDMAN, 1967). Higher doses usually lower the response rate making assessment of performance difficult. However, it seems reasonable to assume that the more intense changes in visual discriminations occur at these higher doses since the intensity of physiological and perceptual changes increases with increasing dosage of LSD in man (HOFFER and OSMOND, 1967, p. 104).

The present experiment was designed to assess the effects of high doses of both Cannabis sativa (marihuana) and LSD on a visual dis-

* Based on a paper presented at the Seventy-sixth Annual Convention of the American. Psychological Association, San Francisco, California, August 30—September 3, 1968.

Supported in part by a grant from the National Research Council of Canada and by a grant from the Dalhousie Medical Faculty Research Fund.

The author is indebted to Miss JEAN POOLE for technical assistance.

crimination task in pigeons. Previous studies have assessed LSD effects on the dimensions of brightness, flicker, and hue. Such objective studies report an improvement in accuracy of a brightness discrimination (BLOUGH, 1957a); an improvement in accuracy of a flicker discrimination (BECKER *et al.*, 1967); and little change in hue discrimination performance with low doses (BERRYMAN *et al.*, 1962). These findings can be compared with numerous subjective reports of visual perceptual changes under LSD treatment in man (HOFFER and OSMOND, 1967, pp. 111ff). Since most subjective reports of alterations in visual perception occur with colors and forms, the present procedure (described below) was designed to separate responding along the dimensions of color and form. The procedure is somewhat related to the matching procedure employed by BERRYMAN *et al.* (1962) with the exception that the task used here required the animal to acquire the complex discriminations or "concepts" of form and color. This procedure also relates to evidence (DEWS, 1955) that complex behavior, involving color perceptions, is more susceptible to drug effects than simple discriminations of hue.

Method

Subjects. Four loft-reared homing pigeons were used as subjects. All animals were naive and maintained at 70% of their free-feeding weights. All birds weighed approximately 250 g at the start of the experiment.

Apparatus. All animals were trained in an operant discrimination unit equipped with three response keys. The two side keys were located 5.71 cm from the center key. A minimum force which moved the response keys .1524 cm was required before a microswitch was operated and a response recorded. The required forces on the three keys were equated by means of a stylus pressure gauge. Digital display units were located behind each key. While the pattern displayed on the center key varied (see Procedure below), only white light was displayed on the side keys. A food magazine was located below the center key.

Procedure. During a 10 sec intertrial interval (ITI) all keys were dark. A trial started when the two side keys were illuminated with white light and the center key was illuminated with one of three groups of patterns. The patterns on the center key were either a white triangle (the standard), or another form, or a color. The form and color patterns consisted of standard digital display patterns commercially available[1].

[1] The stimuli projected by the display units included the patterns incorporated into Grason-Stadler (West Concord, Massachusetts, U.S.A.) patterns no. 151, 153, 156, 158 and Lehigh Valley Electronics (Fogelsville, Pennsylvania, U.S.A.) pattern groups no. 692 and 696.

Forms included squares, circles, rectangles, lines, dots, striped lines, various tilted lines and stripes, crosses, etc. Forms were either black on a white surround or white forms on a black surround. Colors included red, blue, green, yellow, amber, white, and various mixtures of each (changes in hue, saturation, and brightness). If the standard white triangle appeared, the animal had to complete a fixed-ratio 10 (FR 10) schedule on the center key in order to earn a three-second access to mixed-grain reinforcement. Responses to the other two keys had no programmed consequences. If a color appeared, responses to the right key (white light) were reinforced on the same FR 10 schedule. Responses to the other two keys had no programmed consequences. If a form appeared on the center key, responses to the left key (white light) were reinforced on FR 10. Responses to the other two keys had no programmed consequences. Reinforcement terminated a trial, followed by the ITI and the start of a new trial. A daily session consisted of 39 trials: 13 standard triangles, 13 colors, and 13 forms. Patterns were randomly presented within a session and digital display units were randomly changed between sessions.

Preliminary Training. All subjects were initially exposed to 30 Preliminary training sessions. The first 10 sessions consisted of 40 trials of the standard triangle alone. The second 10 sessions consisted of 20 trials of the standard triangle and 20 trials of colors, all randomly alternated. The third 10 sessions consisted of 20 trials of the standard triangle and 20 trials of forms, randomly presented. Subjects were then trained on 40 sessions of 39 trials each: 13 triangles, 13 colors, and 13 forms. At this point discrimination performance reached stable rates (defined as five consecutive sessions with less than a 10% daily change in discrimination ratios) and training was terminated.

Drug Sessions. Subjects were then given a series of drug sessions in counterbalanced order. All drug sessions consisted of 21 trials (7 triangles, 7 colors, and 7 forms) all randomly presented in extinction. Drug sessions were conducted in extinction to prevent the occurrence of a reinforcement serving as a cue for responding and to prevent the occurrence of learning under a "dissociated" drug state (cf. BINDRA and REICHERT, 1967). The first trial was terminated by 10 correct responses and was followed by a 10 sec ITI. The second and subsequent trials were terminated by 10 correct responses or 15 sec, whichever occurred first.

Pharmacological Procedure. Drugs tested included 0.9% sodium chloride (saline), LSD[2], Bromolysergic acid diethylamide (BOL-148)[2], Cannabis sativa[3], and sodium pentobarbital (Nembutal). A petroleum

[2] Sandoz Ltd., Basle, Switzerland.

[3] Division of Narcotic Drugs, United Nations Office at Geneva.

ether extract of 100 grams of Cannabis sativa was prepared according to the procedure described by CARLINI and KRAMER (1965). The fine colloidal suspension which resulted contained 50 mg of the oily extract per milliliter. In order to equate dosages of Cannabis with LSD, a minimal effective dose (MED)was independently determined for a group of eight pigeons. The MED was defined as the smallest dose $\pm$ .25 mg which produced complete cessation of responding (zero responses per minute) for a minimum of six hours. The MED for LSD was determined to be approximately 1 mg/kg and for the Cannabis extract 40 mg/kg. Subsequently, each of the four animals in this experiment were tested with a 50% MED of LSD (500 µg/kg), 50% MED of Cannabis (20 mg/kg), 75% MED of LSD (750 µg/kg), and a 75% MED of Cannabis (30 mg/kg). All drugs were administered intraperitoneally in a volume of 1 ml/kg one hour prior to testing. In the case of sodium pentobarbital, a five minute pretreatment time was used. At least seven regular training sessions intervened between successive drug sessions.

Results

Fig. 1 shows discrimination ratios for each bird in means for blocks of five training sessions. The discrimination ratios are computed as follows: Correct responses to all keys are added together and expressed as a percentage of total correct and total incorrect responses. For example, responses to either of the side keys when a standard triangle is displayed are scored as incorrect responses. Only responses to the center key are scored as correct for this triangle display. Similarly, responses to either the center or left keys when a color is displayed are scored as incorrect responses, etc. It is clear from Fig. 1 that after 40 sessions of training all birds had stable baseline performance between 80—90%. Fig. 2 shows the discrimination ratios for each bird during each drug session. The arrangement of doses is not a chronological one as doses were administered in counterbalanced order. During the pretest performance (represented by means for each bird for the last 10 sessions of training prior to the first drug session), all birds were performing between 80—90% (Drug Session 1). Accuracy of performance remained relatively unchanged by treatment with saline, BOL, or Cannabis (Drug Sessions 2, 6—9). However, the 500 µg/kg dose of LSD (Drug Session 4) produced a significant loss in accuracy ($t = 5.28$, $p = .02$)[1]. The 750 µg/kg dose of LSD (Drug Session 5) also produced a significant loss in accuracy ($t = 3.38$; $p = .05$). The dose of 300 µg/kg of LSD is suggestive of a trend toward improved accuracy but this effect is not significant ($t = 2.20$, $p = .20$). Pentobarbital (10 mg/kg) produced some decrement in performance (Drug Session 10) but this was not significant ($t = 1.80$, $p = .20$). In addition, some decrements in response

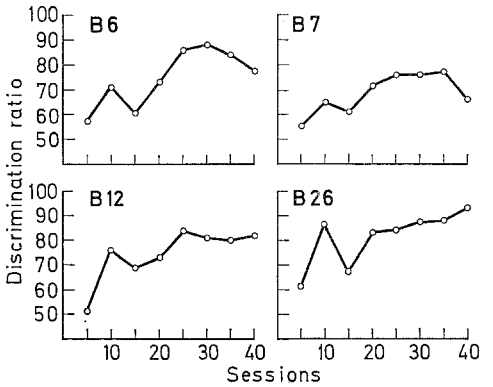

Fig. 1. Discrimination ratios during for each bird in means for blocks of five sessions

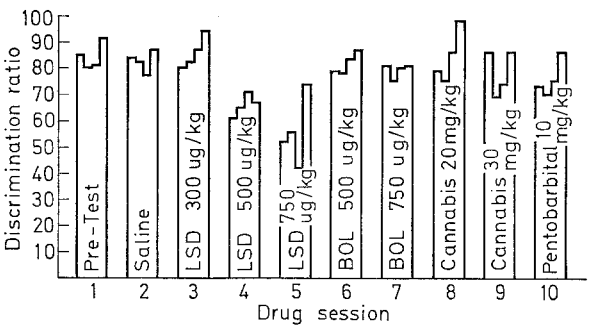

Fig. 2. Discrimination ratios for each bird during each drug session. Each step on the histograms represent an individual bird in the following repeating order: B6, B7, B12, and B26

rates were observed at increased doses of LSD and Cannabis for some birds. Often the birds did not start responding in the test situation for several hours. Table 1 shows the mean times for completing the first test trial for each drug session. It is clear from this Table that the higher doses of LSD and Cannabis produced the longest suppression of responding.

Table 2 shows the mean distribution of errors during all drug sessions. Errors are scored according to the following procedure: Responses to the center key when either a form or color is displayed is scored as a standard (triangle) error. Responses to the right key (color) when either a form or standard triangle is displayed is scored as a color error. Responses to the left key (form) when either a color or the standard triangle is displayed is scored as a form error. During the pre-test mean of

Table 1. *Mean time (in minutes) for completing the first test trial in each drug session (n = 4)*

Pre-Test	Saline	LSD 300 μg/kg	LSD 500 μg/kg	LSD 750 μg/kg	BOL 500 μg/kg	BOL 750 μg/kg	Cannabis 20 mg/kg	Cannabis 30 mg/kg	Pento-barbital 10 mg/kg
.127	.124	.235	12.104	58.186	.131	.128	1.200	1.700	3.002

Table 2. *Mean distribution of errors during all drug sessions (n = 4)*

Errors	Pre-Test	Saline	LSD 300 μg/kg	LSD 500 μg/kg	LSD 750 μg/kg	BOL 500 μg/kg	BOL 750 μg/kg	Cannabis 20 mg/kg	Cannabis 30 mg/kg	Pentobarbital 10 mg/kg
Form	53.3	52.5	33.3	7.1	11.9	63.2	55.8	8.7	3.3	60.6
Standard	2.4	6.4	3.7	5.2	4.8	1.1	2.3	5.0	2.1	3.2
Color	44.3	41.1	63.0	87.7	83.3	35.7	42.9	86.3	94.6	36.2

Table 3. *Total responses (correct and incorrect responses) and total errors made by each bird during each drug session*

	B6		B7		B12		B25	
	Total Responses	Errors	Total Responses	Errors	Total Responses	Errors	Total Responses	Errors
Pre-Test	459	69	488	98	482	92	429	39
Saline	255	51	256	51	205	62	239	48
LSD 300 μg/kg	207	41	248	50	212	28	212	13
LSD 500 μg/kg	217	87	205	82	218	65	182	73
LSD 750 μg/kg	229	115	168	84	232	139	203	61
BOL 500 μg/kg	170	51	245	98	254	51	263	53
BOL 750 μg/kg	209	42	204	61	211	42	214	43
Cannabis 20 mg/kg	216	65	219	66	182	36	204	20
Cannabis 30 mg/kg	190	38	287	115	203	61	74	15
Pentobarbital 10 mg/kg	218	65	225	68	206	62	228	46

10 sessions, errors were relatively equally distributed between form and color keys. However, with 300 μg/kg of LSD there is a significant increase in the number of color errors ($x^2 = 15.31$, $p = .001$, $df = 1$)[4]. This increase is more apparent and significant as the dose of LSD is increased (500 μg/kg: $x^2 = 82.55$, $p = .001$, $df = 1$; 750 μg/kg: $x^2 = 66.48$, $p = .001$, $df = 1$). Equal doses of BOL show no significant change in error distribution. Both doses of Cannabis also show a significant increase in color errors (20 mg/kg: $x^2 = 77.13$, $p = .001$, $df = 1$; 30 mg/kg: $x^2 = 104.01$, $p = .001$, $df = 1$). Pentobarbital did not produce a significant change in error distribution.

The error distribution in Table 2 was computed from the total responses and total errors of each bird during each drug session and these responses are shown in Table 3. The responses under the pre-test condition represent means for the last ten sessions prior to the first drug session. Since these pre-test sessions represent responses during 39 trials, the responses under the various drug sessions (21 trials) should actually be compared to performance under saline (21 trials). Throughout most drug sessions, all birds maintained total response levels similar to the saline levels.

Discussion

The most apparent aspect of these findings is that large doses of hallucinogenic agents increase responding on a color dimension but not on a form dimension. High doses of LSD produce a decrement in discrimination performance while doses of Cannabis (equated with LSD on the basis of effectiveness in suppressing responding) do not effect accuracy (Fig. 2). Since higher doses of both LSD and Cannabis suppressed responding for several minutes (Table 1), it could be argued that the subsequent distribution of errors observed when the animals did resume responding was a result of a decrement in response output. However, the total response output under the various drug conditions was usually within the expected levels observed under treatment with saline (Table 3). This finding is consistent with Blough's (1957b) suggestion that the effects of LSD on accuracy outlast the initial depression of total response output.

Several interpretations of these findings suggest themselves. Firstly, it may be argued that these hallucinogens simply break-down stimulus control. While this notion may explain the decrement in performance observed under high doses of LSD (Fig. 2) it fails to account for the accuracy of performance under comparable doses of Cannabis. Indeed,

[4] In the analysis of error distributions, only the "observed" distribution of errors between the color and form keys was considered and compared to the "expected" pre-test distribution.

a break-down in stimulus control might also be expected to distribute errors more equally among the three keys. Since performance under pentobarbital was suggestive of a decrement in accuracy with no concomitant change in error distribution, one must view this stimulus control interpretation with caution.

Alternatively, a particularly attractive but more speculative explanation is that animals were reporting perceptual events. Animals under LSD and Cannabis may have been reporting color changes when no color changes were occurring on the center key. Since color errors did not prevail under BOL, which is similar in action to LSD except for the psychological effects and EEG activation (HOFFER and OSMOND, 1967, p. 94), the results seem to be at least a consequence of the centrally acting properties of the drugs if not the hallucinogenic properties themselves. Because of the procedure employed for scoring errors in this study, it remains possible that color errors may have resulted from failures to detect forms and not from "color hallucinations". In any case, errors in this discrimination task occurred differentially as a function of treatment with hallucinogens.

References

BECKER, D. I., J. B. APPEL, and D. X. FREEDMAN: Some effects of lysergic acid diethylamide on visual discrimination in pigeons. Psychopharmacologia (Berl.) **11**, 354—364 (1967).

BERRYMAN, R., M. E. JARVIK, and J. A. NEVIN: Effects of pentobarbital, lysergic acid diethylamide and chlorpromazine on matching behavior in the pigeon. Psychopharmacologia (Berl.) **3**, 60—65 (1962).

BINDRA, D., and H. REICHERT: The nature of dissociation: effects of transitions between normal and barbiturate-induced states on reversal learning and habituation. Psychopharmacologia (Berl.) **10**, 330—344 (1967).

BLOUGH, D. S.: Effects of drugs on visually controlled behavior in pigeons. In GARATTINI, S., and V. GHETTI: (Eds.): Psychotropic drugs. Amsterdam: Elsevier 1957 a.

— Some effects of drugs on visual discrimination in pigeon. Ann. N. Y. Acad. Sci. **66**, 733—739 (1957 b).

CARLINI, E. A., and C. KRAMER: Effects of cannabis sativa (marihuana) on maze performance of the rat. Psychopharmacologia (Berl.) **7**, 175—181 (1965).

DEWS, P. B.: Studies on behavior, II the effects of pentobarbital, methamphetamine and scopolamine on performance in pigeons involving discriminations. J. Pharmacol. exp. Ther. **115**, 380—389 (1955).

HOFFER, A., and H. OSMOND: The hallucinogens. New York: Academic Press 1967.

R. K. SIEGEL
Department of Psychology
Dalhousie University
Halifax, Nova Scotia, Canada