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Effects of Lysergic Acid Diethylamide on the Spontaneous Activity and Visual Receptive Fields of Cells in the Lateral Geniculate Nucleus of the Cat

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Summary. The effects of LSD on neuronal activity in the LGN were studied in cats anaesthetised with urethane. LSD was given in doses of 25 μg, 100 μg, 200 μg and 300 μg per cat. Changes in neuronal activity were compared with those observed in a control population of cells recorded from animals that had received 0.5 ml of physiological saline or no treatment. The spontaneous firing rate, the responses to light stimuli delivered to the centre and to the surround regions of the receptive fields were all depressed by the drug. There was a dose response relationship which was almost identical (slope, b = —0.19 to —0.20) for each of these aspects of LGN neuronal activity. In a given cell changes in spontaneous activity were not correlated with changes in the responses to field centre or surround stimulation. Changes in response to field centre stimulation were not predictive of changes in response to field surround stimulation except in the LSD $\geqq$ 100 μg treatment groups. In these groups the variances of the change in spontaneous activity were greater than those in the controls. It is concluded that, in the doses used, LSD does not exert a uniformly depressant action on postsynaptic membranes: the effects observed are consistent with an action on the release of transmitter substance and/or its interaction with receptors. BOL 148, the non-psychoactive analogue of LSD did not completely reproduce the effects of any dose of LSD used in this study. The possible consequences of the action of LSD on LGN neurones for the processing of visual information is discussed.

Key words: LSD — Lateral geniculate body — Single units — Receptive fields — Spontaneous activity — Sensory Processing

Introduction

Small doses of d-lysergic acid diethylamide (LSD) produce profound visual disturbances in man and behavioural changes in animals (see review by Hoffer and Osmond, 1967). Evarts *et al.* (1955) found that small doses of LSD (30 μg/kg) given intra-arterially strongly depressed the postsynaptic field response of the lateral geniculate nucleus (LGN) to shocks applied to the optic nerve. Similar results were obtained by Bishop *et al.* (1958) who also found that when the drug was given intravenously higher doses were required to produce a comparable depression. Evarts *et al.* (1955) showed that LSD, given in quantities many times greater than that required to alter the LGN response, did not affect the response of the cortex to shocks applied to the optic radiation and had only a small depres-

sant effect on the flash-evoked response of the optic tract (in doses of 2.5 mg/kg).

The work of Evarts *et al.* (1955) and Bishop *et al.* (1958) suggests that, in the visual pathways, the LGN is particularly sensitive to LSD. Curtis and Davis (1962) and Phillis *et al.* (1967) used the technique of iontophoresis to apply LSD directly to LGN neurones. They found that the spontaneous activity and the responses evoked by light flashes and by electric shocks delivered to the optic tract were depressed by the drug. None of these studies, however, throws any light on the effects of the drug on the discrete sensory transfer functions of the LGN. The studies of evoked potentials do not provide any direct indication of the effects of LSD on single unit discharges and the iontophoretic studies do not provide any direct evidence of the ways in which the drug might influence the receptive fields of cells in the nucleus. The present experiments were therefore undertaken to analyse the effects of LSD on the spontaneous activity and receptive field properties of single cells in the LGN. These studies extend those of Mouriz-Garcia *et al.* (1969) on a small sample of LGN neurones. A preliminary account of the work has been published (McKay and Horn, 1971).

Materials and Methods

28 adult cats (mean weight 2.87 kg) were used. Anaesthesia was induced by an intraperitoneal injection of a mixture containing a 20% solution of urethane in normal saline (5.0 ml/kg) and sodium pentobarbitone (10 mg/kg), and maintained by additional doses of urethane (1 ml/kg) as required. A polythene cannula was introduced into the saphenous vein, providing a route for the administration of drugs. A similar cannula in the femoral artery was used to monitor blood pressure. The EEG was monitored by means of a stainless steel screw, placed over the right cortex, posterior to the bregma. Each eye was fixed to a stainless steel ring by means of sutures placed through the sclera, posterior to the limbus. The ring was clamped to the stereotaxic instrument. In this way eye movements greater than $\pm$ 15′ of arc were eliminated (Horn *et al.*, 1972). The cornea was protected from drying by means of a contact lens and the retina made conjugate with the testing plane. Tungsten microelectrodes (Hubel, 1957; Horn, 1969) were positioned stereotaxically, and lowered into the LGN. Postsynaptic neurones were identified by the waveform of the spike (Bishop *et al.*, 1962).

Visual landmarks (the optic disc and area centralis) were plotted, on a sheet of paper placed over a screen 1 m in front of the cat's eyes, by means of a reversible ophthalmoscope. The background luminance of the screen was maintained at 4 cdm^{-2} by overhead tungsten lights. Receptive fields were plotted using the technique of Talbot and Marshall (1941) and Hubel and Wiesel (1961). The position of the field, together with its response characteristics were marked on the sheet of paper. The centre and surround regions were outlined in pencil. A spot of light was then focussed on and filled the centre of the field. This spot, duration 0.5 sec,

Fig. 1. *Effects of treatment on spontaneous impulse activity. A*) Treatment is stated below each set of three bars in the histogram and n is the total number of units in each treatment group. Units belonging to one treatment group are classified according to whether the post-treatment firing rate was increased (hatched bars), decreased (black bars) or not changed (open bars), compared with the pretreatment firing rate. The criterion of change using the Mann-Whitney U test, was $p \leqq 0.05$. The numbers above each bar represent the number of units in the class. The height of the column represents this number expressed as a percentage of the total number of cells in that treatment group. *B*) The mean percentage change for each unit is plotted against treatment, positive values being given to an increase, negative values to a decrease in the mean firing rate. Control data are considered to be equivalent to a 0 dose of LSD. The Pearson correlation coefficient was $r = -0.46$. Changes in mean firing rate that were statistically significant are indicated by filled circles, those that were not significantly different by filled triangles

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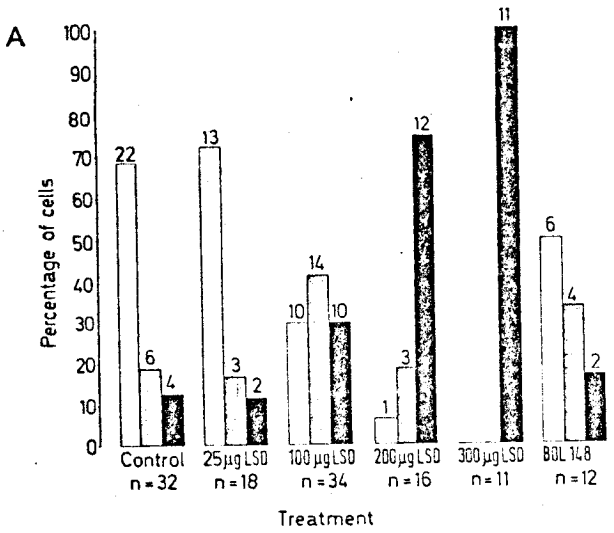
and 1.5 to 2 log units brighter than the background luminance, was presented 20 times at 5 sec intervals, by means of a mechanical shutter. The surround region of the field was similarly stimulated, but by an annulus of light. These responses and also the spontaneous activity of the cell were recorded on magnetic tape (pre-treatment data). After these records had been made, a dose of LSD hydrogen tartrate salt, dissolved in 0.5 ml normal saline immediately before injection, was administered intravenously, over a period of 1 min. The dose given was 25 μg, 100 μg, 200 μg or 300 μg, each approximating to 9, 35, 70 and 105 μg/kg. After the injection the spontaneous activity and the responses to centre and surround stimulation of the receptive field were recorded (post-treatment data). Counts of spontaneous activity were made over 3 min periods before and after treatment with LSD. Post-treatment counting was begun approximately 1 min after injection. This interval was chosen because, in pilot experiments on 24 cells where spontaneous activity was recorded continuously before, during and after the injection, changes, when they occured, appeared within a minute (see Fig. 2 for examples). The 3 min period in which spontaneous activity was recorded was broken down into epochs of 10 sec. The number of impulses in each epoch was counted. Pre- and post-treatment counts were compared using the Mann-Whitney U test (Siegel, 1956). The number of spikes present in the 0.5 sec after the onset ("on" responses) or offset ("off" responses) of the light was counted for each set of 20 stimuli. Data for pre- and post-treatment responses were compared using the same statistical test. In the text, unless otherwise stated, activity is considered to have changed only if the difference was significant at $p \leqq 0.05$. The minimum interval between injections was 1 hr, but usually more than 1 hr elapsed between the end of a study on one cell, and the beginning of a study on the next. In some experiments, the non-psychoactive (Cerletti and Rothlin, 1955) derivative of LSD, 2-brom-lysergic acid diethylamide (BOL 148) was given as the hydrogen tartrate salt in doses of 100 μg dissolved in 0.5 ml normal saline. In other experiments 0.5 ml normal saline alone was given. The variations of spontaneous and evoked activity with time were studied in a group of cells (the "time lapse" group) in experiments in which no injections were given. Spike counts were made as for the regime in which injections were given. Data for the time lapse and saline groups of cells were analysed, and compared. No significant differences were found in either spontaneous or evoked activity. The data from the two groups were therefore pooled and are referred to as the control data. In all treatment groups, unless otherwise stated, 'centre-responses' combine data from "on" centre units with those from "off" centre units; similarly the 'surround responses' consist of data from units with "on" and "off" surrounds. The effect of the noise made by the mechanical shutter on the response of each cell was investigated before and after injection of drugs. No LGN cell was found to respond to the noise of the shutter, either before or after drugs had been administered. 123 cells were studied, and data on field plots were obtained from 105 of them. All statistical tests are two-tailed. At the end of each experiment, the cat was perfused with 10% formol saline and the location of the electrode track checked histologically.

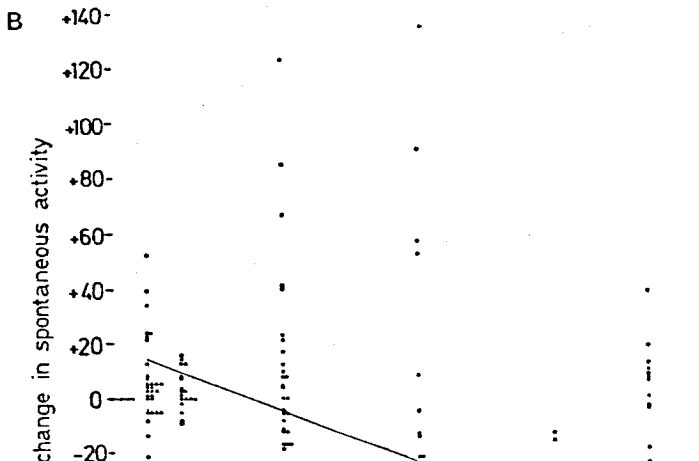
Results

There were no consistent changes of blood pressure or in the electroencephalogram following the administration of LSD.

Effects of LSD on Spontaneous Impulse Activity

Units in a treatment group were classified according to whether the mean spontaneous firing rate after treatment was significantly increased, decreased or not significantly changed from the firing rate before treatment. The number of cells in each class was expressed as a percentage of the total number of cells in the treatment group (Fig. 1*A*). The activity of 10 out of 32 cells in the control group changed significantly. The distribution of the percentages in the BOL 148 group was similar to that of the controls. The distributions in the LSD treatment groups changed as the dose of the drug increased. The percentage of units in the "no change" class gradually fell from 72.2% in the 25 μg group to 0 in the 300 μg group. In contrast, the percentage of units in which the activity decreased follow-





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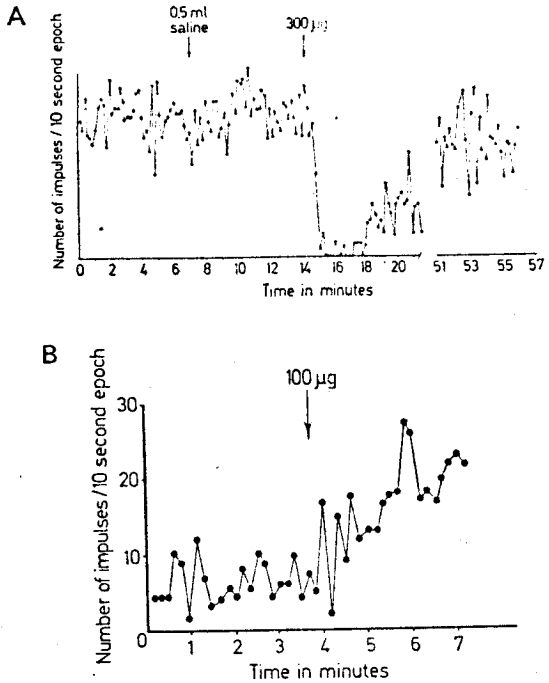

Fig. 2. *Effects of LSD on spontaneous activity.* Data from 2 units are shown. The number of spikes counted per stated interval of time are plotted against time. The arrow indicates the time of injection. *A*) 0.5 ml of saline had no effect on the firing rate, but 300 µg of LSD strongly depressed the discharge, which returned almost to control level within 40 min. *B*) A unit in which spontaneous activity was increased following injection of 100 µg of LSD

ing treatment, gradually increased from 11.1% in the 25 µg group to 100% in the 300 µg group.

The mean percentage change in the spontaneous activity of each unit is plotted in Fig. 1*B* according to treatment. A straight line was fitted by the method of least squares to the LSD treatment data, the control population being taken as 0 dose. The regression coefficient $b = -0.19$ was significantly ($t = 5.39$; $p < 0.001$) different from 0.

The scatter of the points in Fig. 1*B* is not the same for all treatments. The variances of the percentage change in mean firing rate are given in Table 1. The variances of all, except the BOL 148, treatment groups differed from that of the control group. The variance of the 25 µg LSD group was reduced, but the variances of the other LSD groups were increased. In the 100 µg and 200 µg groups, in spite of an overall depression of the discharge, strong excitatory effects were also present. The effects of the drug on the activity of 2 units are illustrated in Fig. 2.

If the effects of repeated injections of LSD were cumulative, the influence of a given dose might be expected to differ according to whether or not the cat had received more than one injection of the drug. The effect of LSD on the mean firing rate of the first unit studied was compared with its effect on that of the last unit studied in the same animal. In all such pairs of cells, the second of the pair

was recorded after a minimum of 3 previous injections. No significant differences were found showing that cumulative effects, if they were present, were too small to be detected.

Table 1. *The variances and variance ratios of the percentage change in mean spontaneous firing rate according to treatment.* NS = not significantly different

Treatment	Variance	Number of units in group	Variance ratio, F, relative to controls	p
Control (0 μg LSD)	273.6	32	1	—
25 μg LSD	46.0	18	5.95	0.001
100 μg LSD	2185.6	34	7.99	0.001
200 μg LSD	1982.0	16	7.24	0.001
300 μg LSD	845.0	11	3.09	0.01
BOL 148	277.2	12	1.01	NS

Effects of LSD on Receptive Fields

Responses to Field Centre Stimulation

The responses of a high proportion (21 out of 36) of the control population of units changed after treatment whereas only a small proportion (3 out of 12 units) in the BOL 148 group did so (Fig. 3*A*). These differences suggest that BOL 148 had a stabilising effect on responsiveness to field centre stimulation. When, however, units were classified according to whether or not their activity changed after treatment, the distribution of the BOL 148 group was not quite significantly ($0.1 < p > 0.05$) different from that of the controls. In the LSD groups, the percentage of units in which the responses were unchanged following injection of the drug fell and the percentage in which responses were depressed increased as the dose was increased.

The mean percentage change in response of all units was plotted according to treatment (Fig. 3*B*). The slope of the straight line fitted to the data from the LSD (including LSD 0) groups was $b = -0.20$. This was significantly ($t = -4.93$; $p < 0.001$) different from zero slope. The variances of the values plotted in Fig. 3*B* were calculated. The variance of the 200 μg group was significantly greater than that of the controls ($F = 2.32$; $p < 0.05$) and the variance of the BOL 148 group significantly smaller ($F = 8.67$; $p < 0.001$). The latter effect is consistent with the trend referred to in the above paragraph. No other variances differed significantly from that of the controls.

Using the criteria referred to in the previous section there was no evidence of a cumulative effect of LSD on the responses to field centre stimulation.

Responses to Field Surround Stimulation

The responses of a high proportion (26 out of 35) of units in the control group changed significantly after treatment (Fig. 4*A*). As the dose of LSD increased from 25 μg to 200 μg the percentage of units unaffected by the drug fell and the percentage in which the response was depressed increased. The mean percentage change in the response to field surround stimulation is plotted for each unit in Fig. 4*B*

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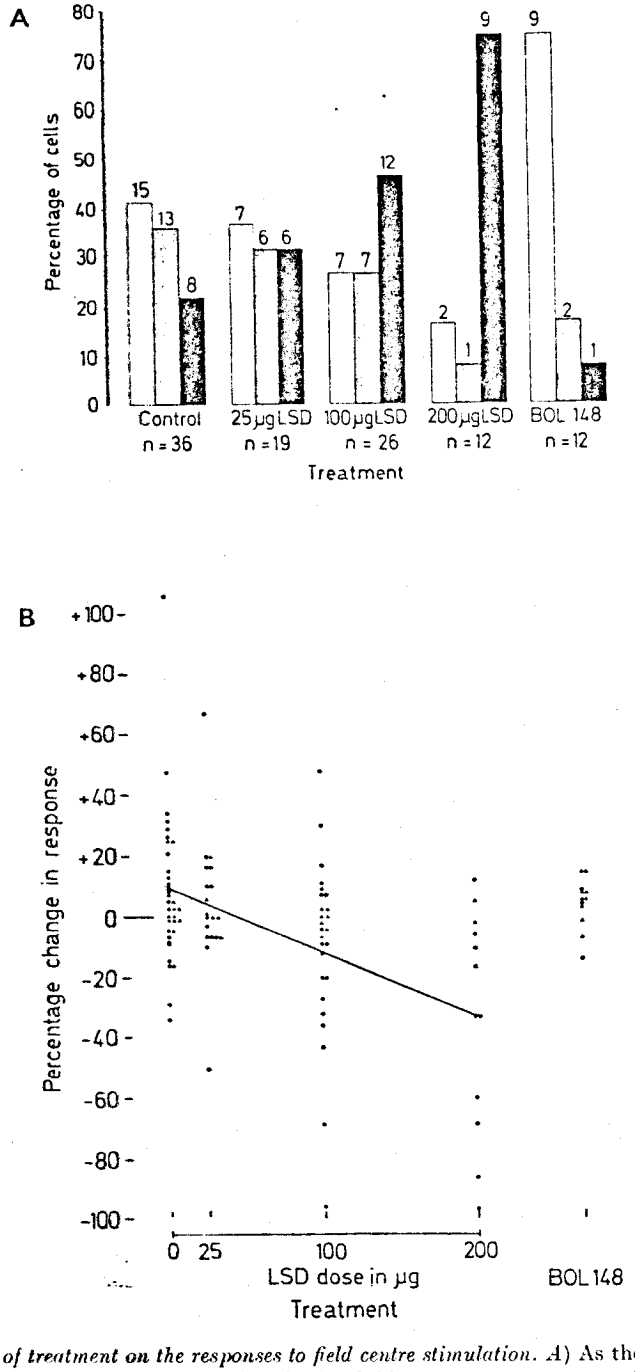

Fig. 3. *Effect of treatment on the responses to field centre stimulation.* *A*) As the dose of LSD increased the percentage of units in which the field centre responses remain unchanged, or increased, gradually fell whereas the percentage of units in which the responses were depressed increased. For further details see legend to Fig. 1 *A*. *B*) Distribution of mean percentage change for each unit according to treatment. The Pearson correlation coefficient was r = —0.46. For further details see legend to Fig. 1 *B*

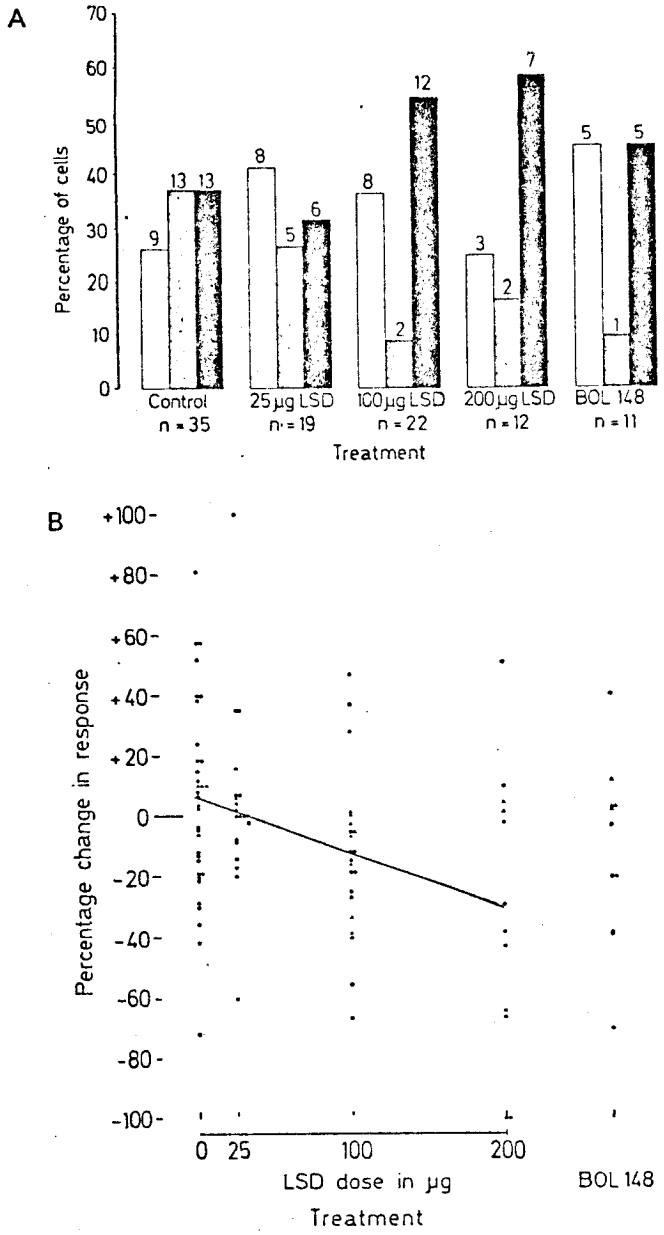

Fig. 4. *Effect of treatment on responses to field surround stimulation. A*) For further details see legend to Fig. 1 *A*. *B*) Distribution of mean percentage change according to treatment. The Pearson correlation coefficient was r = —0.37. For further details see Legend to Fig. 1 *B*

for all treatments. The regression coefficient for the data from the LSD (including the LSD 0) groups was b = —0.19 which was significantly different from zero ($t = -3.69$; $p < 0.001$). The slope of the regression was the same as that for spontaneous activity and almost the same as that for the centre responses (b =

—0.20). None of the variances of the several treatments was different from that of the controls.

There was no evidence of a cumulative effect of LSD on the responses to stimulation of the surround region of the receptive field.

General Considerations

The size and shape of the receptive fields were not influenced by any of the treatments, nor, with 2 exceptions, were the centre and surround responses changed in type, that is from being either pure "on" or pure "off". These exceptions were not investigated further and will not be referred to again.

It is possible that the treatments affected "on" centre responses more than "off" centre responses. Responses in the various LSD groups were therefore broken down (Table 2) according to response type and to whether or not the post-treatment responses were significantly different from the pre-treatment responses. surround responses were classified in the same way. The number of cells within each class was too small to justify statistical analysis so that any conclusion must be tentative. However, from these data and from the combined data for all classes (totals columns, Table 2) there are no strong grounds for supposing that LSD exerted any differential effect on units according to their response type.

Table 2. *Effects of LSD on receptive field responses classified according to type.* Responses to centre or surround stimulation were classified according to whether or not the response was changed following treatment. Data were further broken down by response type "on" or "off". The actual number of units in each class is given at the bottom right hand corner of each box. This number expressed as a percentage of the total in the stated treatment group is given in the middle of each box. For example, the total number of "on" centre units in the 25 μg group was 14. The responses of 9 (64.3%) of these changed and the responses of the remaining 5 (35.7%) were unchanged following administration of the drug

		LSD dose in μg							
		25		100		200		Totals	
Field Region	Response	Changed	Not changed	Changed	Not changed	Changed	Not changed	Changed	Not changed
Centre	On	64.3 9	35.7 5	70.5 12	29.5 5	100.0 5	0.0 0	72.2 26	27.8 10
	Off	60.0 3	40.0 2	77.8 7	22.2 2	71.5 5	28.5 2	71.4 15	28.6 6
Surround	On	40.0 2	60.0 3	50.0 4	50.0 4	57.2 4	42.8 3	50.0 10	50.0 10
	Off	64.3 9	35.7 5	71.5 10	28.5 4	100.0 5	0.0 0	72.6 24	27.4 9

Changes in spontaneous and evoked activity occurred in all treatment groups. Are changes in response to receptive field stimulation correlated with changes in spontaneous activity? This question can legitimately be answered only if a change in spontaneous activity is maintained throughout the period in which the evoked responses are being studied. This condition is satisfied in the higher LSD dose

groups in which the effects on spontaneous activity last from several minutes up to approximately 1 hr. In these groups the regression coefficient of changes in centre and surround responses on changes in spontaneous activity were calculated (Table 3). None were significantly different from zero. Thus, although all parameters of impulse activity were increasingly depressed as the dose of LSD was increased the magnitude of change in spontaneous activity was not predictive of the magnitude of change in the evoked response.

Table 3. *Relationship between changes in spontaneous activity and changes in response to receptive field stimulation.* The mean percentage change in the response to field centre stimulation was paired with the mean percentage change in spontaneous activity in each unit. The regression coefficient, b, was calculated for n pairs. This was done for both 100 μg LSD and 200 μg LSD treatment groups. The same calculations were made for the mean percentage change in surround responses and the mean percentage change in spontaneous activity. The slope of the best-fitting line was compared with 0 slope using the t test. None of the differences were significant

	100 μg LSD		200 μg LSD	
	Centre	Surround	Centre	Surround
b	—0.26	—0.31	+0.21	+0.41
t	—1.29	—1.34	+0.80	+1.21
p	NS	NS	NS	NS
n	25	22	12	12

Are the changes in centre responses independent of the changes in surround responses in a given unit? The regression coefficients of the percentage change in surround response on the percentage change in centre response were calculated for the various treatment groups (Table 4). As the dose of LSD increased, the slope (b) of the best fitting line increased. The slope was marginally different from zero slope for the 100 μg LSD group and highly significantly ($p < 0.01$) different for the 200 μg LSD group. Thus as the dose of LSD was increased a change in the response to field centre stimulation became more predictive of the change in the surround response.

Table 4. *Relationship between changes in response to field centre stimulation and changes in response to field surround stimulation.* The mean change in response to field centre stimulation was paired with the mean change in response to field surround stimulation. This was done for n pairs of means in each treatment group. The slope b of the regression was compared with 0 slope using the t test

	BOL 148	LSD dose in μg			
		0	25	100	200
b	+1.90	+0.17	+0.27	+0.46	+0.96
t	1.90	0.74	0.81	2.08*	3.33
p	NS	NS	NS	NS	$p<0.01$
n	11	34	19	22	12

* For 20 degrees of freedom the value for t at $p = 0.05$ is 2.09

Discussion

The spontaneous activity and responsiveness of a high proportion of units in the control group changed significantly with the passage of time, although there were no changes in the size or shape of the receptive fields. Against this fluctuating background of impulse activity certain effects of LSD appeared quite clearly. The drug depressed spontaneous and evoked activity, the magnitude of the depression and the proportion of units affected increasing as the dose was increased. Superimposed on these effects was another. LSD in doses of $\geqq$ 100 μg increased the variability of the change in spontaneous activity relative to that of the controls.

LSD has no effect on the invasion of optic nerve terminals by action potentials (Evarts *et al.*, 1955) and a possible site of action of the drug may be on the release of transmitter substance from these terminals and/or on the interaction of the transmitter with the postsynaptic membrane (Bishop *et al.*, 1958; Curtis and Davis, 1962; Marchbanks, 1966; Tebēcis and Di Maria, 1972; Farrow and Vunakis, 1972). At higher doses ($\geqq$ 100 μg) changes in the response to field centre stimulation are correlated with changes in the response to field surround stimulation. This result is consistent with a depressant effect of LSD on the postsynaptic cells. However, changes in the spontaneous activity of a neurone were not correlated with changes in the evoked responses in any LSD dose group and, in a given unit, a marked depression (e. g. by 96%) of the response to field centre stimulation might be associated with strong augmentation (e.g. by 85%) of the spontaneous activity. The drug therefore must differentially affect the processes underlying evoked and spontaneous discharges. These findings virtually rule out the possibility that, in the doses used, the drug has a postsynaptic depressant action such as that observed when LSD in high concentration is iontophoretically applied to LGN neurones (Tebēcis and Di Maria, 1972).

The spontaneous discharge of neurones in the LGN is influenced by inputs from the reticular formation (Levick and Williams, 1964) and possibly by neuronal interactions within the nucleus (Fuster *et al.*, 1965; Burke and Sefton, 1966) as well as by inputs from the retina (Levick and Williams, 1964). LSD may interfere with the neuronal system controlling spontaneous discharges such that these discharges are depressed and their fluctuations (Griffith and Horn, 1966) extend over a wider range than in the control population of cells.

BOL 148, which, when administered to humans has a sedative action and does not produce visual disturbances (Cerletti and Rothlin, 1955), had little effect on impulse activity in the LGN. Unlike any dose of LSD, it reduced the variance of the mean changes of responses to field centre stimulation compared with that in the controls. Also unlike any dose of LSD, BOL 148 was without effect on the variance of the mean change in spontaneous activity. The latter finding underlines the possibility mentioned above that one site of action of LSD might be the reticular formation thus indirectly influencing the spontaneous activity (and, possibly, the light evoked responses — see Hotta and Kameda, 1964) of LGN neurones. Nerve terminals containing 5-hydroxytryptamine (5-HT) are present in the reticular formation (Fuxe, 1965). LSD antagonises the excitatory effects of 5-HT on neurones in the reticular formation whereas BOL 148 rarely does (Boakes *et al.*, 1970).

The time course of action of LSD on spontaneous activity and the absence of any cumulative effects of the drug is consistent with the finding in rats that ^{3}H-LSD penetrates the brain within 5 min and disappears 1 hr after intravenous injection (Diab *et al.*, 1971).

Neurones in the LGN are connected to neurones in the striate cortex possessing "simple" receptive fields (Hubel and Wiesel, 1962). If all LGN neurones feeding onto cells with a simple receptive field were uniformly depressed, the responsiveness of these cells might change without any accompanying changes in the organisation of their receptive fields. If, however, the excitability of some of the LGN neurones were depressed and others not, the structure of the receptive fields of the cortical cells might alter. The second possibility is the more probable, since, in a given penetration of the LGN some neurones were encountered in which impulse activity was depressed by LSD whereas in others it was not affected or was increased by the drug. The postulated alterations in the structure of simple receptive fields might be compounded if, as Bishop *et al.* (1971) suggest, inhibitory neurones intervene between cells with these fields and some of the axon terminals of LGN neurones. The response properties of cells with "complex" (Hubel and Wiesel, 1962) receptive fields might also be expected to be influenced by LSD since these cells may receive input both from LGN neurones directly (Hoffman and Stone, 1971) as well as from cells with simple fields (Hubel and Wiesel, 1962). Activity in cells of the visual cortex may lead to perceptual experiences for when the cortex of human subjects is electrically excited, sensations of light are reported (Foerster, 1929; Penfield and Rasmussen, 1952; Brindley and Lewin, 1968). Furthermore, it is likely that the receptive field properties of cortical cells impose constraints on pattern discrimination (Hirsch and Spinelli, 1970; Blakemore and Cooper, 1970). Changes in these properties, secondary to the changes in the LGN, may thus contribute to the disturbances of visual perception that occur following administration of LSD.

A reduction in the spontaneous discharge of LGN neurones might lead to an increased activity in cortical cells which are thought to be tonically inhibited by the LGN discharge (Bishop *et al.*, 1971). If the disinhibited neurone achieved a firing rate that is normally produced when an image falls on the retina, an organism which had received LSD might experience visual sensations in the absence of retinal stimulation. Such sensations are reported (Hoffer and Osmond, 1967) in human subjects who have taken LSD.

Very high doses of LSD might be expected to produce a functional ablation of the LGN. Animals receiving such doses (Evarts *et al.*, 1955; Bishops *et al.*, 1958) behave as if they were blind.

In the present studies, anaesthesia was maintained with urethane. It is possible that this anaesthetic interacts in some way with LSD so that the effects observed are of little physiological interest. This extreme view is unlikely to be correct since the results described are consistent with those obtained from unanaesthetised animals and from animals anaesthetised with barbiturates (Evarts *et al.*, 1955; Bishop *et al.*, 1958; Curtis and Davis, 1962; Phillis *et al.*, 1967; Tebēcis and Di Maria, 1972). The results are also consistent with those of Mouriz-Garcia *et al.* (1969) who studied in unanaesthetised cats the influence of LSD on the receptive fields of 7 LGN cells. They used a standard dose of 50 μg/kg and found that the

responses were strengthened in some cells and weakened in others, a result similar to that found using the corresponding dose (100 μg per cat) in the present study.

Finally it is worth emphasising that the response of a high proportion of cells to stimulation of the receptive field changes "spontaneously". Such changes could account for the fluctuations in receptive field properties of cortical neurones which occur with the passage of time (Horn and Hill, 1969; Bear *et al.*, 1971; Horn *et al.*, 1972; Poggio, 1972; Donaldson and Nash, 1973).

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