Electroencephalography and Clinical Neurophysiology
Elsevier Publishing Company, Amsterdam – Printed in The Netherlands

SUBJECTIVE AND EEG RESPONSES TO LSD IN VISUALIZER AND NON-VISUALIZER SUBJECTS

BARBARA B. BROWN, PH.D.

Experimental Psychiatry, Veterans Administration Hospital, Sepulveda, Calif. 91343, and Department of Psychiatry and Human Behavior, University of California College of Medicine, Los Angeles, Calif. (U.S.A.)

(Accepted for publication: February 5, 1968)

It is popularly accepted that changes in visual perception and visual imagery are major components of the LSD experience. DiMascio *et al.* (1961) found, however, only a 20% incidence of visual perceptual changes in a personality group identified as "athletic" and a slightly lower incidence for an "esthetic" group.

Attempts to evaluate effects of LSD on visual perceptual activities have yielded conflicting results, particularly between objective and subjective evaluations. Hartman and Hollister (1963) found that LSD decreased color discrimination, but increased flicker-induced perception of subjective colors. Edwards and Cohen (1961) reported no differences in color detection. Employing the stabilized image technic, Kohn and Bryden (1965) reported that under LSD the whole target was seen more often, but with distortions. Ostfeld (1961) has shown that LSD affected rod but not cone function of the retina; and further, that visual hallucinatory experience was greater in the blind than in the non-blind.

Recently we reported that visualizers and non-visualizers could be distinguished by their different responses to colored photic flicker (Brown 1966); *i.e.*, individuals with the ability to experience vivid visual imagery showed suppressed photic following to the color red as compared to blue or green, whereas individuals totally lacking this ability showed enhanced EEG photic following responses to red. The present study was undertaken to determine whether the ability for visual imagery and its EEG correlate were related to differences in response to LSD.

METHOD AND MATERIALS

Subjects were obtained from hospital personnel and nearby colleges: sixty-four volunteers were screened for degree of ability for visual imagery based on criteria evolved from earlier studies (Brown 1966, 1968). Only individuals at the two extremes of visual imagery ability were considered for the study. A total of seventeen volunteers, ranging in age between 24 and 35, were obtained: nine subjects (5 males) scored as possessing the ability to experience vivid visual imagery, and eight subjects (4 males) scored as totally lacking this ability. Information on subjective evaluations of visual imagery ability was obtained by engaging the subject in a discussion of the objective definitions of types of imagery. If the questions indicated in Table I were not

TABLE I

Subject classification according to criteria questions for visual imagery ability

	1 Where are the images?			2 See images with eyes open?	3 Images ever block real visual scene?	4 Are images as real as in dreams?
	In front of eyes	Near eyes	Inside head	Yes	Yes	Yes
Visualizers, $N = 9$	9	0	0	9	8	5
Non-visualizers, $N = 8$	0	0	8	2 (possibly)	0	0

answered in voluntary statements, they were then asked directly. Subjects indicating that their visual images were projected, and giving yes answers to 2 of the 3 remaining questions were classified as visualizers. Subjects reporting mental images as being vaguely within the head and giving no answers to 2 of the 3 other questions were classified as non-visualizers. In addition, all subjects were asked about the amount and quality of their dreams.

Following a 90 min recording control period, all subjects of both groups received LSD orally in doses of 50, 75 or 100 μg, depending upon body weight (dosage range of 0.75–1 μg/kg). EEGs were recorded from bilateral, bipolar temporo-parietal, parieto-occipital and occipital needle electrode placements, the latter being from 2 cm above and 2 cm lateral, and 1 cm below and 1 cm lateral to the occipital protuberance. Eye movements were also recorded as a control measure; EOG changes did not contribute new information and are not reported.

EEGs and EOGs were recorded continuously throughout the experiments, except for a 45 min period immediately post-drug, on a Grass Model 6 EEG and on analogue tape. Evaluations of alpha activity (all from occipital recordings) were made from four 3 min samples of spontaneous EEG activity both when the eyes were open and when the eyes were closed, obtained from the last 60 min of the control period and from the interval between 3.5 and 4.5 h post-drug. Sample sets were averaged for comparisons. Amplitude of alpha waves was measured directly from the EEG records. Frequency was quantified by passing the taped data through a 7–15 c/sec active band pass filter and the output fed to the amplitude discriminator accessory unit of the CAT 400. Wave period analysis was then carried out using the CAT 400 to count positive-going zero crossings occurring within a 250 or 500 msec analysis time, discriminating to 0.625 or 1.25 msec intervals. Results were recorded on an X–Y plotter. The percentage of time that alpha was present in the EEG was determined from the counts of the zero crossings as read out by the TMC Resolver-Integrator accessory unit of the CAT. For comparisons, these percentages were normalized to a 10 c/sec frequency.

The effect of mental activity on EEG and EOG activities was determined by requesting the subjects to attempt visualization or recall of specific objects named by the experimenter (*e.g.*, his desk; a sailboat), and by giving the subjects mental arithmetic tasks (*e.g.*, 123 times 6), allowing 90 sec for each attempt. Each of the 2 types of task was given 3 times during both control and post-drug periods. The EEG responses were determined as indicated above, using results obtained from the 2 trials of the last 60 min of the control period and from the 3–4 h interval post-drug.

Brain electrical responses to color were obtained using red, blue and green flicker presented for 15 sec periods randomly until each color had been presented 7 times (total of 315 sec). The photic stimuli were delivered by a Grass PS-4 stimulator to a large diffusion screen placed 2 ft. in front of the subject's face. White light was given at an intensity setting of 2, and the colors at a setting of 8. The colors had been subjectively equalized for intensity and saturation to each other and to white (by adjusting gelatin filters) by a panel of 4 individuals not involved in the study. The average transmission wave lengths in mμ were 665 for red, 470 for blue and 540 for green. Prior to presentation of the first color series the frequency eliciting optimal EEG following between 5 and 13 c/sec, was determined in each subject using white light. For comparisons, 10 sec samples from all 7 presentations of each color, omitting the first second of each sample, were averaged for both frequency and amount of EEG following. Recordings from the parieto-occipital areas were used for analysis. The data were analyzed as indicated above for the parameters of alpha.

The Ishihara test for color blindness was given at the end of the control period; no major color deficiencies were found in any of the subjects.

RESULTS

1. *Subjective responses*

Discussions of visual imagery with prospective subjects differed considerably for the two subject groups. Visualizers invariably volunteered the answers to two or more of the questions (Table I) whereas non-visualizers contributed little and it was necessary to ask the questions directly.

Without exception, the effect of LSD in visualizer subjects was reported as enhancement of sensory perceptual activity, accompanied by verbalization and voluntary information about the changes. This was typified by the remark of one subject who stated that after LSD he could no longer block out real visual scenes by his visual images because perception of the visual world was so intense.

In contrast, non-visualizers reported experiencing minimal change in color perception, limited to intensity and without changes in depth, texture, position or proportion. Such information had to be elicited by questioning as the non-visualizers concentrated their remarks on conceptual material, particularly regarding self-examination and personal philosophy.

The two groups had in common a "smiling response" which signalled onset of LSD response. This spontaneous relaxation or disinhibition occurred in all subjects as smiling and/or giggling lasting 5–10 min or more, and was more intense in the visualizers. Maximal changes in both groups occurred in approximately 3 h, but the duration of the subjective responses was only 5–8 h in non-visualizers while four of the visualizer group retained effects for 12 h and longer.

All subjects reported dreaming during sleep. The incidence of dreaming in color was the same

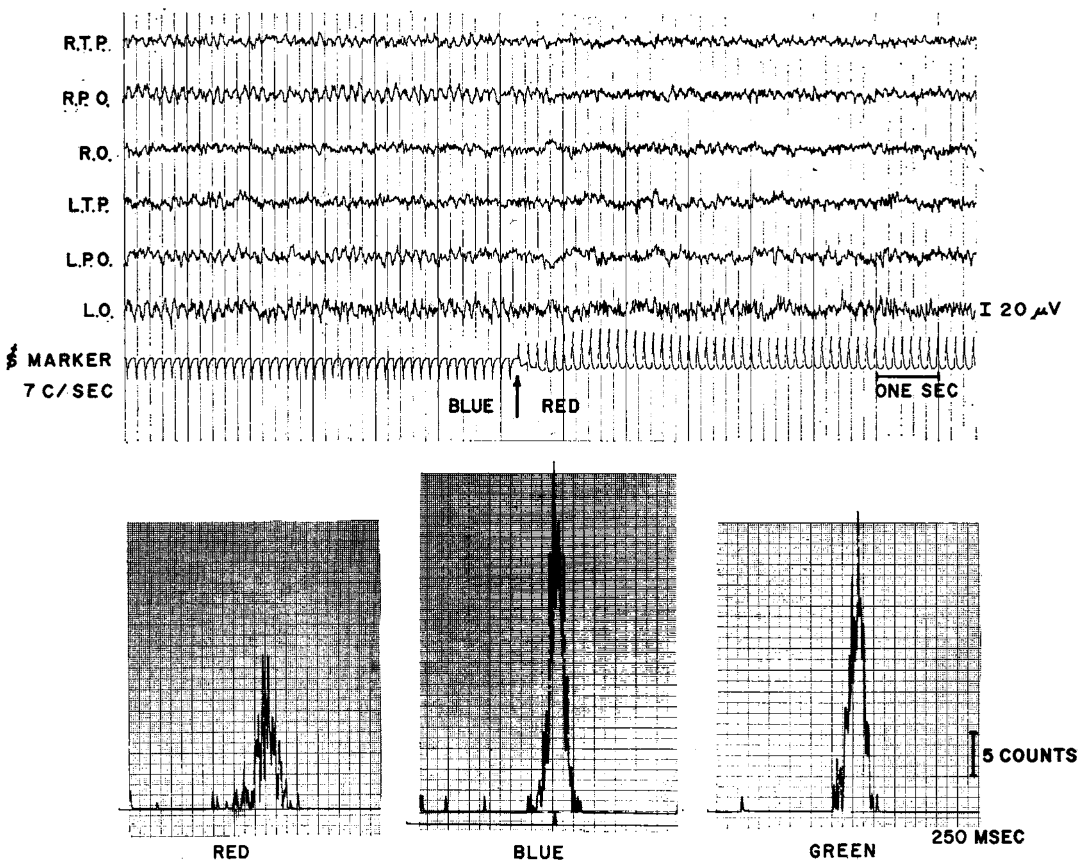

Fig. 1

EEG following responses of a typical visualizer to colored photic flicker. *Top*: Excerpts from EEG records. *Bottom*: Abscissa represents time interval between positive-going zero crossings of filtered data. Total range is 0–250 msec. Ordinate indicates the count of zero crossings for each interval. 70 sec samples of each color were analyzed. Abbreviations: R.: right, and L: left; T.P.: temporo-parietal; P.O.: parieto-occipital; O.: occipital.

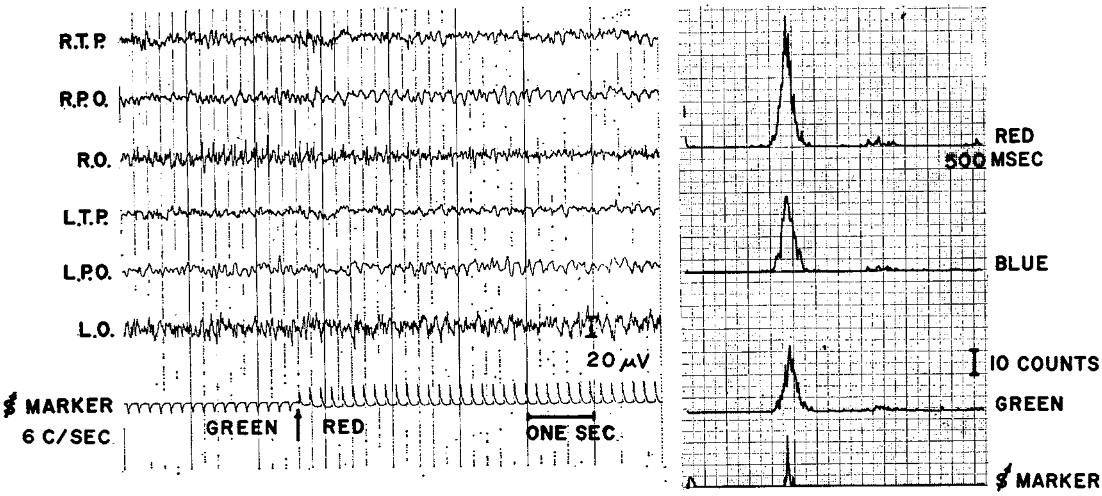

Fig. 2

EEG following responses of a typical non-visualizer to colored photic flicker. *Left*: Excerpts from EEG records. *Right*: Abscissa represents time interval between positive-going zero crossings of filtered data. Total range is 0–500 msec. Ordinate indicates the count of zero crossings for each interval. 70 sec samples of each color were analyzed.

for both groups. The non-visualizers reported more enthusiastically about the clarity of their dreams than did the visualizers.

2. *EEG following responses to colored photic flicker*

Examples of the color specific responses found for visualizer and for non-visualizer subjects are given in Fig. 1 and 2. It can be noted that the following responses and the changes in response with change in color are most obvious in the parieto-occipital recordings.

The amount of EEG following elicited for each color (see Method) was expressed as per cent and the results were averaged for each color for both subject groups. The results for both control- and post-LSD periods are graphed in Fig. 3.

Differences in responses between the two groups for blue and green were significant at the 1% level and for red at the 5% level as determined by the Chi Square Median Test. The responses to color for the two groups were affected quite differently by LSD. In visualizers, the following responses to red and blue were significantly reduced from control values at the 1% level (Student's *t*). Their responses to green were essentially unchanged. In the non-visualizer group, the responses to blue and green were augmented, that for blue being significant at the 1% level (Student's *t*), whereas the responses to red were not affected.

LSD increased the harmonic following in both visualizers and non-visualizers. Harmonic following showed the red specific responses similarly as did following at the fundamental. An example is shown in Fig. 4. It was observed that the three visualizers with EEG beta activity as the harmon-

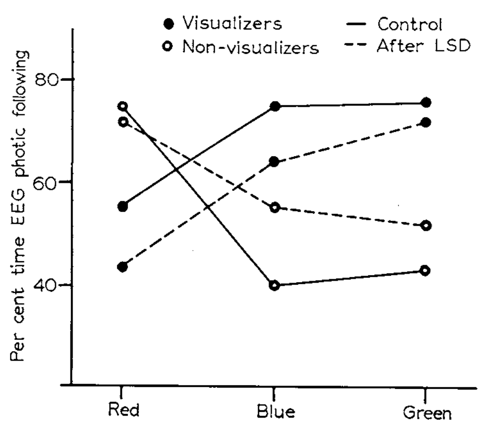

Fig. 3

Changes in the average per cent of time in which EEG responses occurred to red, blue and green following LSD in visualizer and non-visualizer subjects.

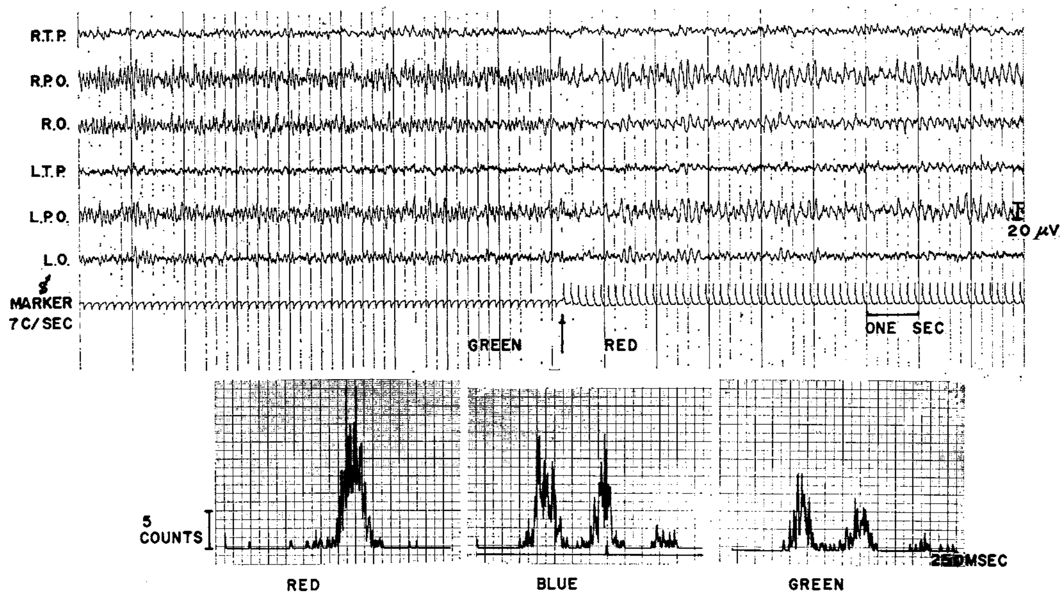

Fig. 4
Color specific EEG photic following responses manifest as changes from fundamental to harmonic following. *Top*: Excerpts from EEG records. *Bottom*: Abscissa represents time interval between positive-going zero crossings of filtered data. Total range is 0–250 msec. Ordinate indicates the count of zero crossings for each interval. 70 sec samples of each color were analyzed.

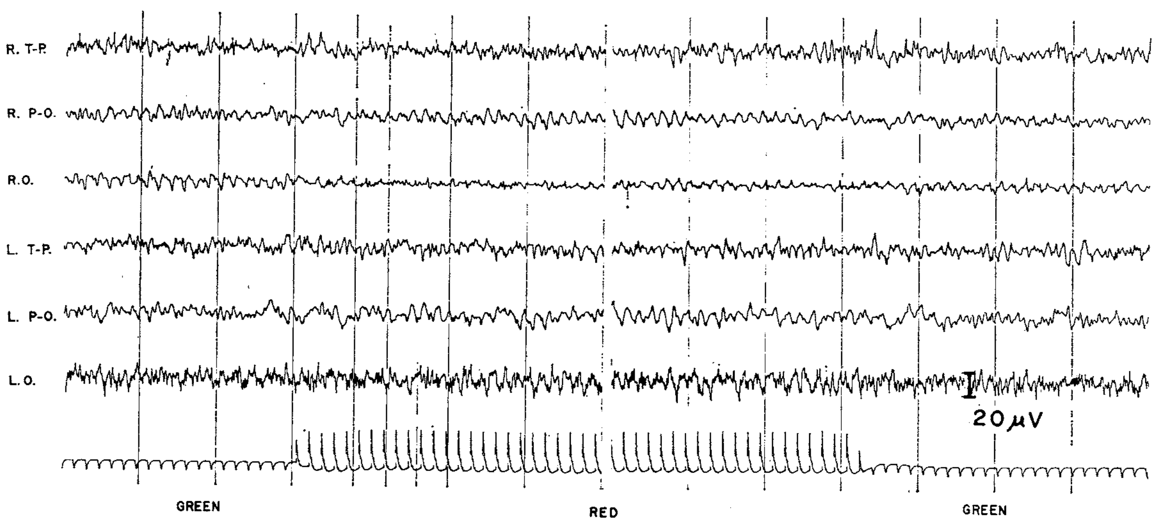

Fig. 5
Example of localized EEG differences in responses to colored photic flicker in the same hemisphere (non-visualizer). Bottom trace indicates color signal marker. EEG following responses shift between RPO and RO when color of stimulus is changed.

ic of alpha, did not exhibit harmonics in their photic following responses. In contrast, three visualizers and one non-visualizer having slow alpha activity (7.5–8.2 c/sec) during control spontaneous EEG recording, not only showed increased alpha frequencies of 1.5–2 c/sec after LSD, but also exhibited harmonic photic following post-drug.

Two unusual findings were encountered, neither affected by LSD. In one visualizer a differential responsiveness to blue and green, reciprocal in the two hemispheres occurred consistently. In one non-visualizer subject a differential responsiveness between red and green occurred between two adjacent sites of the right hemisphere. An example of the latter is given in Fig. 5.

3. *Associated activities. EEG*

Average values and changes for 3 parameters of alpha activity are given in Table II. Levels of EEG activation were generally greater in non-visualizer subjects, indicated by significant differences in both frequency and amplitude of alpha waves. Following LSD, EEG activation was reduced significantly in the non-visualizers but not in the visualizers. Increased activation levels in visualizers after LSD is suggested by the changes in frequency and amount of alpha found during the eyes open samples. In three of four visualizers with high beta activity content (> 50%), beta was manifest as the precise harmonic of the alpha frequency, but disappeared after LSD.

Alpha correlates of mental activity

Results in Table III indicate that attenuation of both the amplitude and abundance of alpha activity occurred in both subject groups during the mental activity tasks. In visualizers, the attenuation of alpha activity during attempted visual recall was not affected by LSD although a quantitatively similar attenuation occurring during mental arithmetic was reduced by 50%. In contrast, non-visualizers responded to LSD by a 50% loss of the attenuation of alpha during

TABLE II

Results for alpha activity parameters before and after LSD

Group	Condition	Averaged alpha activity					
		Eyes open			Eyes closed		
		Frequency c/sec	Amplitude μV	Abundance %	Frequency c/sec	Amplitude μV	Abundance %
Visualizers	Control	9.8	26	28	10.2	37	65
	LSD	10.6*	31	21*	10.0	52	67
Non-visualizers	Control	10.7**	20	23	9.9	19**	52
	LSD	10.6	30*	39*,**	10.0	32*	68*

* Different from control at the 1% level (Student's *t* test).
** Different from visualizers at the 1% level (Chi Square Median Test).

TABLE III

Effects of LSD on alpha activity during mental tasks

Group	Condition	Averaged alpha reduction			
		Attempted visual recall		Mental arithmetic	
		Amplitude %	Abundance %	Amplitude %	Abundance %
Visualizers	Control	65	75	67	70
	LSD	68	51	20*	41*
Non-visualizers	Control	51	45	63	50
	LSD	18*	17*	43	50

* Significantly different from control at the 1% level (Student's *t* test).

attempted visual recall, but the responses during mental arithmetic were little affected.

DISCUSSION

The different characteristics found between individuals capable of vivid visual imagery and those who totally lack this ability appear to contribute importantly to the type of both subjective and EEG responses to LSD. The two groups experienced quite different types of subjective responses to LSD, those of the visualizer being largely involved with enhanced visual perception and visual imagery, while responses of the non-visualizers were concerned chiefly with conceptual activity. Responses of the visualizers were overtly both more intense and of longer duration.

The differences in color specific responses between visualizers and non-visualizers were also affected quite differently by LSD, and would appear to parallel the reported differences in visual perception and visual imagery. The mechanisms underlying the differences in brain electrical activity between the two groups may be related to the mechanisms concerned in EEG activation. Following LSD, photically induced activation was decreased in non-visualizers (enhanced following), but was further increased in visualizers (decreased following). If differences in rhythmic activity of photic following responses relate to EEG activation as do differences in rhythmic activity in the alpha range, then the less rhythmic activity produced (*i.e.*, by flicker), the greater the EEG activation. This inference is consistent with the results indicating reduced activation levels in non-visualizers after LSD and increased activation levels in visualizers. The apparently dual action of LSD under different conditions of CNS excitability has been reported (Brown 1957).

Attenuation of alpha during mental activity (eyes closed) has been attributed to visual imagery (Golla *et al.* 1943) and to attention (Drever 1955; Walter and Yeager 1956; Mundy-Castle 1957). In the present study it appeared that under LSD these 2 components were discriminated. It appears likely that visualizers employed visual imagery, and that the attention needed for the mental arithmetic task was diminished after LSD. Most visualizers reported being too occupied with colored visual imagery after LSD to concentrate on problems effectively. In contrast, non-visualizers appear to have relied upon attention for both tasks, and after LSD were less capable of attempting imagery.

The fact that non-visualizers report vivid visual imagery during dreaming contains the implication that many additional individual differences in the central processing of color data may be uncovered. This is also suggested by the findings regarding color specificity of particular recording areas.

SUMMARY

1. Subjects who reported possessing vivid visual imagery ability responded to LSD by enhanced visual perceptual and visual imagery activity, whereas subjects completely lacking this ability experienced little or no change in visual perception or imagery but responded by increased conceptual activity. Non-visualizers, however, reported vivid visual imagery during dreaming.

2. EEG responses of visualizers and non-visualizers to spectral flickering light were reversed for the two groups and were affected differently by LSD.

3. EEG responses indicated activation effects of LSD in visualizers and decreased EEG activation in non-visualizers.

RÉSUMÉ

RÉPONSES SUBJECTIVES ET EEG AU LSD CHEZ DES SUJETS À IMAGINATION VISUELLE

1. Des sujets qui possèdent une capacité vive dans l'imagination visuelle, répondent au LSD par l'élévation de la perception visuelle et de l'activité imaginative visuelle, tandis que des sujets manquant complètement de cette capacité ne manifestent que peu ou pas de changement dans la perception visuelle ou l'imaginaire visuel mais répondent par l'élévation de l'activité conceptuelle. Les "non-visuels", cependant, rapportent un imaginaire visuel vivace pendant le rêve.

2. Les réponses EEG des "visuels" et "non-visuels" à une lumière spectrale en éclairs sont

inverses pour les deux groupes et sont affectés de façon différente pour les deux groupes par le LSD.

3. Les réponses EEG indiquent des effets d'activation du LSD chez les "visuels" et une diminution de l'activation EEG chez les "non-visuels".

The author gratefully acknowledges the technical assistance of J. E. Shryne Jr.

REFERENCES

Brown, B. B. Lysergic acid diethylamide antagonism of certain drugs. *Ann. N.Y. Acad. Sci.*, **1957**, *66*: 677–685.

Brown, B. B. Specificity of EEG photic flicker responses to color as related to visual imagery ability. *Psychophysiology*, **1966**, *2*: 197–207.

Brown, B. B. Visual recall ability and eye movements. *Psychophysiology*, **1968**, *4*: 300–306.

DiMascio, A., Rinkel, M. and Leiberman, J. Personality and psychomimetic drugs. *3rd World Congr. Psychiat. Proc.*, **1961**, *2*: 933–936.

Drever, J. Some observations on the occipital alpha rhythm. *Quart. J. exp. Psychol.*, **1955**, *7*: 91–97.

Edwards, A. E. and Cohen, S. Visual illusion, tactile sensibility and reaction time under LSD-25. *Psychopharmacologia (Berl.)*, **1961**, *2*: 297–303.

Golla, R., Hutton, E. L. and Walter, W. G. The objective study of mental imagery. I. Physiological concomitants. *J. ment. Sci.*, **1943**, *89*: 216–222.

Hartman, A. M. and Hollister, L. E. Effect of mescaline, lysergic acid diethylamide and psilocybin on color perception. *Psychopharmacologia (Berl.)*, **1963**, *4*: 441–451.

Kohn, B. and Bryden, M. P. The effect of lysergic acid diethylamide (LSD-25) on perception with stabilized images. *Psychopharmacologia (Berl.)*, **1965**, *7*: 311–320.

Mundy-Castle, A. C. Electrical responses of the brain in relation to behavior. *Brit. J. Psychol.*, **1957**, *44*: 318–329.

Ostfeld, A. M. Effects of LSD-25 and JB-318 of tests of visual and perceptual functions in man. *Fed. Proc. (Symposia)*, **1961**, *20*: 876–883.

Walter, R. D. and Yeager, C. L. Visual imagery and electroencephalographic changes. *Electroenceph. clin. Neurophysiol.*, **1956**, *8*: 193–199.

Reference: Brown, B. B. Subjective and EEG responses to LSD in visualizer and non-visualizer subjects. *Electroenceph. clin. Neurophysiol.*, **1968**, *25*: 372–379.