Agents and Actions 1, 190-197 (1970). PSI 265 a

Psilocybin-Induced Contraction of Nearby Visual Space

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Abstract

Using apparent fronto-parallel plane (AFP) monitoring techniques, the relative stability of the abathic plane, i.e. Euclidean visual space, was investigated in 16 volunteers with a median age of 23.5 years under 160 μg/kg psilocybin-induced ergotropic arousal. Handwriting area and pressure were also measured in the same subjects.

Drug-induced contraction of nearby visual space was inferred from changes of AFP curvature and tilt, as well as from increased handwriting area at drug peak. The 'rising horizon' (Rennert) in the drawings of schizophrenics is also considered a manifestation of the contraction of visual space and is described in terms of an arousal-dependent transformation of constancies. The 'projection' of central nervous system activity as experience 'out there' is also discussed as an arousal-dependent learned constancy.

Introduction

Among the most sensitive of man's visual perceptions is the binocular judgment of depth. Stereopsis, as it is commonly called, is based on the detection of horizontal disparities in the two retinal images of as little as ten seconds of visual angle [1]. Such discrimination must depend heavily on the character and stability of the dioptrics of the two eyes [2], on the quality of fusion of the two pathway images, and on the integrity of higher perceptual processes. Having explored the influence of the psychotomimetic[2]) drug psilocybin on spatial distortion thresholds [6] and on preferential brightness [7], we will now examine a third constancy-dependent feature of vision [8]: the geometry of nearby visual space and its psilocybin-induced alterations. Some initial questions are: (1) Which specific features of spatial geometry are altered? (2) Can these changes be isolated and quantified? (3) Can they be accounted for?

Methods

In this study aberrations, i.e. curvature (H) and tilt (R), of the apparent frontal plane (AFP) were used as indices of psilocybin-induced changes in the visual space of 16 subjects, 10 males and 6 females with a median age of 23.5

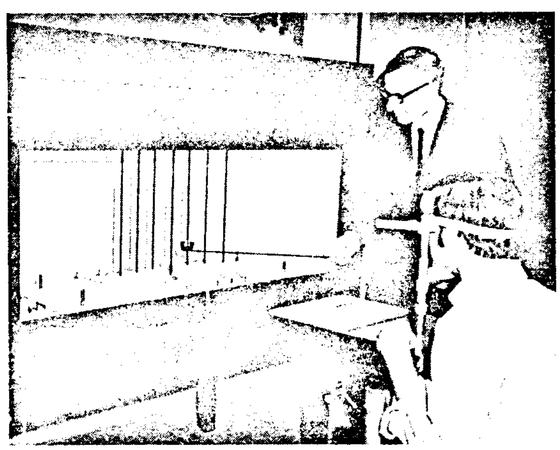

Figure 1
View of a subject positioned before the apparent frontal plane (AFP) apparatus. During test sessions the examiner and all but the rod midsections are masked from the subject's view by a 'field-stop' (not shown). Small sighting devices, fixed to either side of the head rest, allow continual monitoring of the subject's corneal apices to prevent rotation of his facial plane.

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[2]) The cross-tolerance between LSD, psilocybin and mescaline [3, 4] as well as their characteristic square-wave pattern of saccadic eye-movement [5], mark these drugs as *the* psychotomimetic, psychodysleptic or hallucinogenic drugs.

years, prior to (T_1) and 90 minutes (T_2), 180 minutes (T_3) and 270 minutes (T_4) after the administration of 160 µg/kg psilocybin. The manifest aniseikonia of each of the subjects was measured using his maximum visual acuity correction (which was also the correction used during AFP determination), and was found in no case to exceed 0.5% with the usual clinical technique.

During the test, the subject was maintained securely in a chin and forehead rest by a head strap (see Fig. 1). The corneal apices, i.e. the anterior poles of the corneas, were continually monitored to control possible rotation of the facial plane. The subject was *to position the six movable rods*, located 4°, 8° and 12° to the right and left of a fixed reference rod one meter in front of him, into a frontal plane parallel to his facial plane, through instructions to the experimenter. The subject was instructed to direct all the rods into a single frontal plane perpendicular to his lines of sight while fixating on the reference rod. Except for horizontal retinal image disparity, all depth-cues were eliminated by forcing the subject to view only the mid-segments of the rods through a rectangular 'field-stop', 32° horizontally and 16° vertically. The rods, themselves, were matt black, subtending a visual angle of $4^1/_2$°, against a uniform white background of 60 foot-Lamberts, and constituted a controlled spatial display at a constant state of brightness adaptation. Six AFP determinations were made during each ten-minute test-period. Each mean rod position and its standard deviation was used when describing the visual plane at each test-period, i.e. at T_1, T_2, T_3 and T_4. Since each point in the figures represents the mean of six observations (a total of 36 decisions for each mean AFP) at four successive 90-minute intervals, each figure is based on 144 point-settings.

Immediately before the T_1 AFP determination, and at T_2 and T_3, each subject performed a 'handwriting test', which consists of copying with fountain pen four times a 28-word text on separate sheets of paper fastened to a clipboard [9, 10]. The area of each sample is then measured, and the standard deviation (S.D.) of the four samples in each test calculated, as described in reference 9.

Results

Perhaps our most important result is that, under these closely controlled conditions, a subject's apparent frontal plane (AFP) is

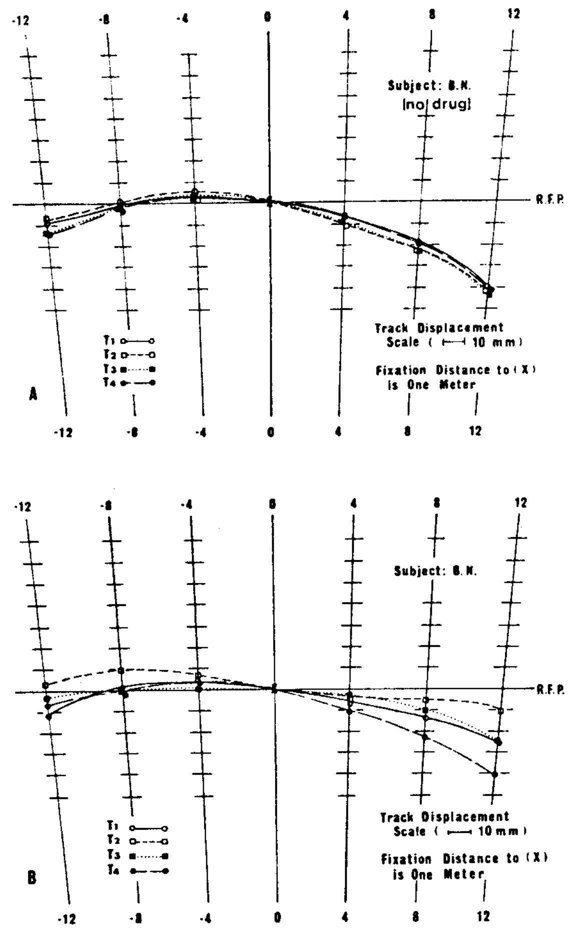

Figure 2
Co-ordinate transformation of the apparent frontal (visual) planes (AFP), as viewed from above. The six lateral points of each curve represent the mean of six measurements. The scaled lines of our system correspond to the tracks on which the carriages of the rods move, designed to converge on a point midway between the two eyes at the facial plane. Displacements of the AFP are measured relative to the rectillinearly flat plane (RFP), i.e. parallel to the facial plane, along the scaled tracks.
A. Display of the stability of an individual's AFP, determined at T_1, T_2, T_3 and T_4, i.e. four times at 90-minute intervals under *no-drug* conditions.
B. 160 µg/kg psilocybin-induced *akatastesia* (instability) of the AFP in the same individual. The drug was orally ingested immediately after completion of the T_1 (control) measurements. The T_2 measurements coincide with the peak activity of the drug, whereas T_3 marks the decline and T_4 the termination of drug activity (270 minutes after T_1).

reproducible to a high degree. Such stability allows reliable assessment of drug-induced changes. The narrow range of fluctuations of both curvature (H) and tilt (R) of the AFP under *no-drug* conditions in a representative subject B.N. is illustrated in Figure 2A. This high degree of individual reproducibility of the AFP is also implied in the significant positive correlation between the S.D. for the most stable AFP points and the S.D. on handwriting area, a psychomotor parameter. The correlation[3]) between the S.D.'s on these two variables is significant ($r = 0.622$, $N = 16$, $p < 0.01$). The correlation between the S.D. of the least stable AFP point[4]) and the S.D. of the handwriting area ($r = 0.546$, $N = 16, p < 0.05$; see Table 1) is also significant. These correlations were not unexpected since we have for some time used an individual's S.D. on a simple or complex perceptual or behavioral task to predict direction and extent of the ensuing drug-induced perceptual-behavioral change [11, 12].

The psilocybin-induced (T_2–T_1) changes in curvature and tilt of the AFP are summarized in Table 2: curvature (H) is positively correlated with T_2–T_1 handwriting area, i.e. the greater the drug-induced increase in handwriting area, the less concave the curvature of the AFP ($r = 0.550$, $N = 13, p < 0.05$). In fact, fourteen of our sixteen subjects showed this drug-induced progression of concavity toward flatness. Drug-induced increase in handwriting area is also positively correlated with AFP tilt (R), which can be interpreted as magnification of one (in terms of pin positions the furthest) side of visual space, the right side in most cases ($r = 0.558$, $H = 13$, $p < 0.05$)[5]). This instability of the AFP within the right visual field, or *dextro-akatastesia*, is best illustrated in Figure 3A, while the less common *levo-akatastesia* is illustrated in Figure 3B. The most commonly occurring akatastesia, namely that of the entire visual field, is illustrated

Table 1
Data illustrating variability on two different perceptual tasks in 10 male and 6 female volunteers: the Pearson Product Moment correlations between S.D. on handwriting area and S.D. on the most stable as well as least stable points of the apparent frontal (visual) plane (AFP), are significant ($r = 0.622$, $N = 16$, $p < 0.01$ and $r = 0.546$, $p < 0.05$). Stability, as used here, is a retrospectively determined characteristic of an individual's visual space and is measured as relative change of mean positions of the two 12° AFP points at T_1, T_2, T_3 and T_4.

Subjects' initials and sex	S.D. of handwriting area in cm² at T_1	S.D. of most stable AFP point in mm at T_1	S.D. of least stable AFP point in mm at T_1
R.S. ♂	2.55	6.01	4.39
J. M. ♂	2.84	2.14	2.85
R. Sm. ♂	3.33	3.85	4.24
B.M. ♂	3.45	4.89	5.38
S.S. ♂	3.72	4.93	7.73
B.N. ♂	3.73	2.09	5.37
G.M. ♂	4.58	1.04	2.39
L.C. ♂	5.23	3.54	6.73
J.S. ♂	7.66	4.55	6.55
T.K. ♂	8.93	2.80	2.69
C.S. ♀	5.20	4.99	3.54
M.W. ♀	6.50	4.52	5.90
Y.F. ♀	7.98	5.24	6.48
A.S. ♀	8.11	6.39	7.87
J.H. ♀	10.07	7.55	6.28
E.A. ♀	14.54	8.70	9.52

3) All correlations in this paper are Pearson product-moment correlations (r).

4) The two most consistently active points of the AFP, i.e. the 12° position points, were selected as indices of stability. The most stable point of the AFP is, therefore, defined here as that 12° point which exhibits the *least* cumulative movement based on its successive mean locations at T_1, T_2, T_3 and T_4. See, for example, the left side of Figure 2B.
The least stable point of the AFP, on the other hand, is that 12° point which exhibits the *most* cumulative movement, based on its successive mean locations at T_1, T_2, T_3 and T_4. See the right side of Figure 2B. In 14 out of 16 individuals this progression of mean locations was directly related to the intensity of the drug experience, whereas the most stable point seldom moved with such predictability.

5) The anticipated relation between unilateral magnification of visual space, i.e. hemi-akatastesia, and handedness and eyedness was tested and found statistically not significant.

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S.D. of least stable AFP point in mm at T_1
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Table 2
Data showing the psilocybin-induced, i.e. T_2–T_1 increase, in handwriting area (column 2), and drug-induced curvature of the AFP (column 3) ($r = 0.550$, $N = 13$, $p < 0.05$). Also shown are drug-induced increase in handwriting area (column 1) and the drug-induced tilt of the AFP (column 4) ($r = 0.558$, $N = 13$, $p < 0.05$), as well as drug-induced tilt of the AFP (column 4) and drug-induced total handwriting pressure (average force) (column 5) ($r = 0.509$, $N = 13$, $p < 0.05$).

Subjects' initials and sex	Δ Hand-writing area in cm² (T_2–T_1)	Δ Curvature AFP (T_2–T_1)	Δ Tilt AFP (T_2–T_1)	Δ Hand-writing pressure in 10^4 dyn (T_2–T_1)
L.C. ♂	−7.2	0.0063	−0.146	−38.1
R.S. ♂	0.1	−0.0056	−0.242	−11.5
S.S. ♂	3.5	0.0115	−0.301	− 6.9
G.M. ♂	4.98	0.0052	−0.011	2.3
J.M. ♂	11.2	0.0034	0.402	20.4
T.K. ♂	19.1	0.0054	0.086	13.9
J.S. ♂	34.4	0.0028	0.123	30.1
J.H. ♀	6.5	0.0096	0.120	−29.2
E.A. ♀	9.5	0.0007	−0.062	10.7
A.S. ♀	12.5	−0.0013	0.224	12.6
M.W. ♀	19.5	0.0044	0.038	14.3
C.S. ♀	28.5	0.0228	0.127	10.5
Y.F. ♀	91.2	0.0191	0.308	6.4

in Figure 4[6]). Finally, the correlation between drug-induced decrease in handwriting pressure and AFP tilt (R) is a significant one ($r = 0.509$, $N = 13$, $p < 0.05$; see Table 2).

Discussion

We have measured certain psilocybin-induced transformations of nearby binocular space, and find that AFP shape, tilt, symmetry and the relative activity of left and right sides may vary independently or together. Before

[6]) The position at T_1 of the least stable point in Figures 3A, 3B and 4 was found significantly different ($p < 0.001$) from its position at T_2.

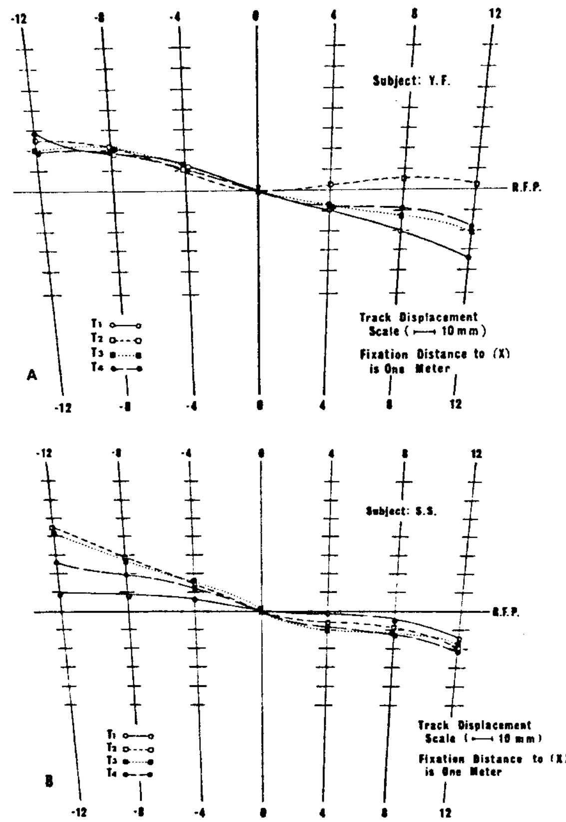

Figure 3
Illustration of psilocybin-induced hemi-akatastesia, specifically, of the right visual field (dextro-akatastesia) in 4A, and of the left visual field (levo-akatastesia) in 4B.

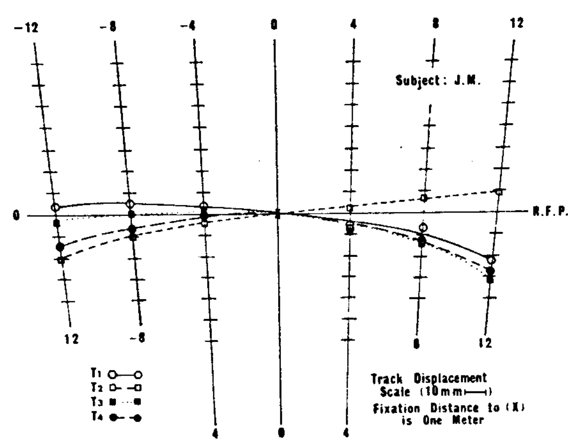

Figure 4
Illustration of psilocybin-induced akatastesia of the whole visual field, representing changes in both curvature and tilt of the AFP.

interpreting these data, several concepts must be considered.

First, it must be noted that a *tilt* of the AFP can be induced by placing a meridional magnifier before one eye while viewing the plane binocularly [1]. In fact, the degree of tilt, as it occurs clinically in cases of aniseikonia (literally: 'not identical images'), is commonly expressed in terms of percent difference of magnification between the two retinal images. *Curvature* of the AFP, on the other hand, appears dependent on the correspondence of receptors in the two retinas, particularly on the equal topographical distribution of those receptors assigned the same visual direction in each retina and throughout the visual pathways [2].

Finally [13], a decrease in the concavity of the AFP pin positions can be observed as fixation distance is increased to a point called the abathic distance[7]) (at which an AFP determination results in a linear alignment of the pins, commonly one to two meters from the subject). Conversely, then, a *reduction* in concavity of the AFP can be interpreted as an *approaching* of the abathic 'plane', i.e. contraction of the distance between the abathic 'plane' and the subject. Inasmuch as our subjects did exhibit a psilocybin-induced reduction in concavity of the AFP, these results can be interpreted as a contraction or closing-in of nearby visual space. This psilocybin-induced transformation of the abathic distance is illustrated in Figure 5, where we have projected along a time axis KIENLE's representation of the abathic distance as a member of a family of AFP's [15].

With these concepts in mind, we can now interpret the psilocybin-induced transformations of nearby visual space. Several contributing influences may alter the shape of the AFP: dioptric, motor[8]) and cognitive. Of these, we will be concerned here chiefly with the cognitive, ascribing its basis to a transformation of visual *constancies* as defined by FISCHER [8] and discussed by HILL [16]. These constancies (for example: size, brightness, color, shape, hue, gestalt, etc.) are ordering representations of experience which phylogenetically and ontogenetically develop through the coordination of sensory experience and motor performance, culminating in a stable environment. The aniseikonic effects produced by both drug and optical stimuli suggest, for example, that subjects are experiencing their partially (or perhaps completely) uncorrected aniseikonia at drug peak.

These transformations are not restricted to perceptual, i.e. visual space, but have been observed in mental, imaginary or hallucinated space by the subjects of KNOLL et al. [17]. Under the influence of the psychotomimetic drugs LSD, psilocybin or mescaline, all of which induce a state of ergotropic (central) arousal, they reported that nearby three-dimensional objects seen with mescaline, such as plastic forms or metallic machine parts, appear within a very close and shallow space. On the other hand certain objects which seemed to occupy a deeper volume of

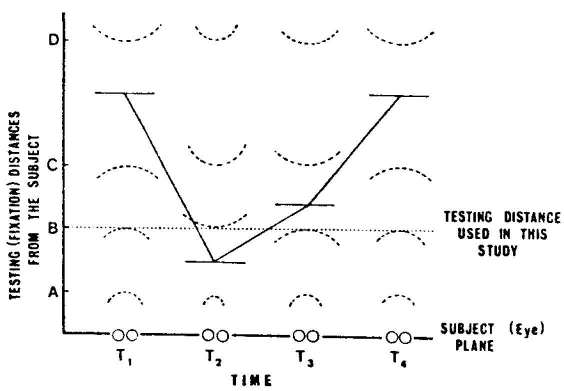

Figure 5
Psilocybin-induced shortening of nearby visual space: a schematic representation of the inferred movement of a subject's abathic distance during a psilocybin experience. The dotted line B marks the testing (fixation) distance at which the central pin of the instrument in Figure 1 was located, while distances A, C and D represent other possible fixation distances. The progression of the AFP with increased fixation distance from concave, to flat, to convex (relative to the subject), is taken from Helmholtz. The curvature of the AFP measured at distance B was used to infer the position of the abathic distance, following Helmholtz's scheme, at T_1, T_2, T_3 and T_4. Note that the dashed curves represent pin positions and *not* inferred compensatory transformations, i.e. the configuration, of the subject's visual space.

[7]) The term 'abathic distance' was coined by LIEBERMAN [14], based on a concept introduced by HELMHOLTZ [13].

[8]) Specific dioptric examples would include a shift of the posterior nodal point of the eye or a change of the angle (δ) between the optical axis of the eye and the geometric axis of the eye and retina, as might result from crystalline lens shift. Aberrations resulting from increased pupil diameter must also be considered [2]. Changes of phoric angle and accommodative state are possible motor factors.

space, and in particular the artificial landscapes (of roads, bridges, tunnels and other manmade constructions) receded far into space with seemingly endless perspectives [17].

According to taste and school of thought, one can stress either the similarities or differences between the psychotomimetic drug-induced acute and reversible experimental state (model psychosis [18]) and an acute schizophrenic episode. It remains, nevertheless, that striking similarities exist between the two states of ergotropic arousal (central sympathetic excitation) despite the fact that an acute, reversible experience is compared with an acute, involuntary episode of a process nature.

Another similarity between the two states can now be added, in the light of our data. The drug-induced enlargement of nearby visual space common to both may also account for the drug-induced enlargement of handwriting area. That ergotropic arousal, whether drug-induced or 'naturally' occurring, results in increased handwriting area has been well substantiated [9, 19, 20]. Conversely, the administration of tranquilizers results in a dose-dependent *decrease* of handwriting area, and a progressive diminution in the size of the drawings of patients [21, 22]. Moreover, witnesses of a holdup overestimate three to four times in their excited state the caliber of the gun pointed at them, while potentially helpful persons, actually nearby, are described as far, far away [23].

The extensive and careful work of RENNERT [24, 25, 26, 27] also substantiates our contention that ergotropic arousal contracts visual space and, through the enlargement of the visual angle of given details, results in an elevation of the horizon. RENNERT has for years studied the angle of perspective in the drawings of schizophrenic patients. He found acuteness of the schizophrenic state to be significantly related to the height of the horizon, i.e. angle of perspective or 'vertical displacement of the visual angle', in his patients' drawings. In fact, using a ruler, RENNERT can predict the remission or relapse of his patients from the positions of the horizons in their pictures. At the onset of a schizophrenic episode the horizon gradually ascends and may even disappear. Simultaneously, a map-like perspective or 'bird's-eye view' of the landscape results, with houses and other significant figures appearing in the foreground.

KRUS et al. [28, 29] have shown that central excitatory drugs, like LSD and isocarboxazid, raise the so-called 'apparent horizon', i.e. that point in space perceived to be at eye level, while the tranquilizers reserpine, tetrabenazine, chlorpromazine and meprobamate lower apparent eye level. Moreover, KRUS found a linear dose-response relationship between LSD and apparent eye level [28].

We suggest that the LSD dose-dependent raising of the apparent eye level and the 'natural' arousal-dependent raising of the horizon in the drawings of schizophrenics are both analogous to the psilocybin-induced enlargement of nearby visual space that we measured with the AFP and with handwriting area increase. These changes, together with psilocybin-induced changes in brightness preference [7] and spatial distortion thresholds [6], can be interpreted as transformations of *perceptual* constancies [8]. *Conceptual* factors, however, are at least as important in maintaining the stability of the world, as exemplified by Wittreich's data showing that an aniseikonic lens-induced distortion of the human figure is differentially resisted according to the degree of familiarity of the observer with the figure [30, 31]. Specifically, less distortion, i.e. more readaptation, was always reported in a spouse than in a stranger; less in a mutilated than in a normal figure; and Navy recruits reported less distortion of authority figures than of non-authorities. Children describe less distortion in a parent than in a stranger and, most important of all, the younger the child, the less developed is his ability to readapt to distortions, emphasizing the gradually-learned perceptual-conceptual nature of constancies. Even phantom sensations, which are readaptation phenomena to maintain the constancy of the self [32], do not appear if amputation is performed before the age of four years [33].

How can it be that objects and events are interpreted – by man the self-referential system – as being 'out there', *beyond* the boundaries of his body, while their source is in altered central nervous system activity *within* the body? We hypothesize that this 'projection' is also one of those gradually acquired ordering re-presentations which we have called constancies. The child slowly learns through sensory-motor experience to erect a model 'out there' which corresponds to his central nervous system activity, but the newborn's 'reality' is actually his central nervous system activity itself, although this is forgotten as he learns his lessons in space and time constancies. Ultimately his complete amnesia will be taken by society as proof of his maturity, and he will conduct his life in (container) space and (chronological) time [8].

Our contention that projection is a learned constancy is also supported by BENDER'S observation that schizophrenic children 'do not experience hallucinations of the projected type like adults, but only of the introjected type. They hear voices inside their head or other parts of the body, feel that they originate inside themselves and do not feel persecuted by them' [34].

It should be emphasized that the projection of our central nervous system activity as location in space and time was learned at and is hence bound to the lower levels of arousal characteristic of our daily survival routines. This paper has shown that, with an increase in the level of central sympathetic excitation, a gradual contraction of this projection is experienced. In fact, the degree of contraction could be regarded as a measure of the excitation, and a measure of the relative dependence of the mind upon the biological substratum which generates it. Thus, at normal levels of arousal, the mind, i.e. the perceptual-behavioral interpretation, is largely independent of the central nervous system activity it interprets.

The farther we depart on the perception-hallucination continuum [35] of higher and higher levels of arousal, from the normal through the creative, psychotic, catatonic and, ultimately, to the mystical ecstatic state [23], the more complete is the transformation, or unlearning, of constancies. In fact, it has been well documented that input, or outside in-formation, is gradually reduced along this continuum [36, 37, 38]. For example, Saint Teresa of Avila tells us in her autobiography that, at the peak of a mystical experience. ...the faculties are lost, because closely united with God. Then the soul neither hears nor sees nor feels. While it lasts, none of the senses perceives or knows what is taking place [39]. Space, then, which was gradually established in ever-widening circles during childhood, gradually contracts with increasing arousal and ultimately disappears[9]).

Acknowledgments

This study was supported by NIMH Grant 1 RO3 MH17633-OI and a General Support Grant administered by the Ohio State University College of Medicine. We thank Sandoz Pharmaceuticals, Basel, Switzerland, and Dr. John A. Scigliano, Executive Secretary FDA-PHS Psychotomimetic Agents Advisory Committee, Bethesda, Maryland, for generously providing us with psilocybin (under IND-3530). We are also grateful to Peter Gwynne, M.D., Mary Ralstin, Thomas R. Kappeler and Robert B. Miller for their everpresent interest and devoted competence.

Received 24 March 1970.

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[9]) Müsset im Naturbetrachten
Immer eins und alles achten:
Nichts ist drinnen, nichts ist draussen;
Denn was innen, das ist aussen.

Epirrhema, Goethe.

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