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An Electroencephalographic Analysis of Personality-Dependent Performance under Psilocybin

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Abstract

An electroencephalographic analysis of personality-dependent psychomotor performance was investigated in 11 volunteers under 160 μg/kg psilocybin-induced ergotropic arousal. Significant psilocybin-induced changes in mean energy content of EEG, reaction time, and latency and duration of alpha attenuation to photic stimuli were noted in all subjects, as well as significant correlations between EEG parameters, personality types and psychomotor (handwriting) test results. Moreover, a 'clustering' of certain EEG, personality, and handwriting characteristics in specific subjects seems to justify their classification into two general groups.

Psilocybin can impair a particular performance in certain subjects, but may improve the same performance in others. Moreover, certain interindividual differences may disappear in response to the drug, or become manifest only under drug influence.

Introduction

GOLDSTEIN [1] in 1963 reported a decrease in mean energy content* of alpha activity (MEC) and a decrease of its coefficient of variation* (CV) during states of ergotropic arousal* induced by LSD in human volunteers. The quantified EEG parameter of CV was found to be strikingly similar in 'normals' under LSD and in chronic male schizophrenics without any drug. MARJERRISON et al. [2] also found a similar decrease in CV, as well as a relation between such decrease and the hallucinatory activity of acute schizophrenics.

Using the same DROHOCKI [3] integrator[2]) which GOLDSTEIN employed in his studies to measure MEC, we have set out to reproduce and extend GOLDSTEIN's data by differentiating the personality trait-dependent psycho-motor performance of college-age volunteers under psilocybin, another ergotropic arousal-inducing hallucinogen. In addition to MEC and CV, we have also measured changes in reaction time, and latency and duration of alpha attenuation to photic stimuli.

Methods

The subject was seated in a reclining chair in a neutral, moderately lit room, and gold-plated Grass EEG electrodes were placed over his right occipital and midline frontal areas (O_2 and F_z of the international system), with interelectrode impedance kept below 10,000 ohms.

Each subject was instructed to immediately press a button with his right index finger in response to a bright light flashed randomly at intervals of 5 to 20 seconds by a Grass PS 2 photo-stimulator placed 8–10 inches before the subject's eyes. Brain-wave activity, the photic stimulus and the signal from the button switch were recorded on a Grass Modell III EEG recorder (calibration 50 microvolts per 10 millimeters).

Brain-wave activity was fed into a DROHOCKI [3] integrator*, and its output pulses recorded by the Grass recorder as a measure of mean energy content*. The integrator was calibrated so that a 10 Hertz sine wave with a 50 microvolt peak-to-peak amplitude produced 148–152 pulses per 20 seconds, an output verified before and after each session.

After subjects adapted to the laboratory environment, thirty 20-second periods of resting brain-wave activity (with eyes closed) were recorded. The mean number of integrator pulses per 20-second period was an expression of the mean energy content of the subject's brain-wave activity. The coefficient of variation* of the mean energy content was obtained by dividing the standard deviation of the number of pulses per period by the mean number of pulses per period, and multiplying by 100 [4].

Latency* and duration of alpha attenuation* were measured for each of 50 randomly presented photic flashes, and mean values calculated for each block of 10 successive

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[1]) Department of Medicine, Division of Neurology.
[2]) Dr. LEONIDE GOLDSTEIN graciously provided us with the same Drohocki integrator he used in his studies.
* This sign denotes an expression described in the Glossary.

stimuli. After a brief training session, in which subjects were instructed to immediately press a button in response to the light flash (reaction time*), 20 photic stimuli were randomly presented during alpha activity (with eyes closed) and while alpha activity was absent (with eyes open).

The tests were performed on each subject prior to (T_1) and at the peak, i.e., 90 minutes after (T_2) the administration of the moderate oral dose of 160 µg/kg psilocybin, which with mescaline and LSD form the group of classical hallucinogenic drugs.

Subjects were college-age volunteers with a median age of 23 years, satisfactory academic records, and 'normal' Minnesota Multiphasic Personality Inventory [5] profiles. All had established Myers-Briggs* (Jungian) Type Indicator (MBTI) Profiles [6, 7], MacKinnon [8, 9] creativity* scores (Σ [N + P]), and handwriting parameters such as area* (in cm^2), the standard deviation of the area and the total handwriting force* (pressure in 10^4 dynes) averaged over time as the subject copies 4 times on separate sheets of paper a 28-word text under standardized conditions [10].

Results

The results fall in three categories: (1) *Group results* referring to drug-induced (T_2–T_1) changes in the following dependent variables for the entire sample of subjects: mean energy content (MEC), its coefficient of variation (CV), latency and duration of alpha attenuation to photic stimuli, and reaction time; (2) *Intra-group results* revealing the influence of personality traits, as measured by the Jungian Myers-Briggs Type Indicator, upon drug-induced changes in the EEG; and (3) *Intercorrelations* among our dependent and independent variables.

(1) *Group results:* All 11 subjects displayed normal (clinical control) EEG recordings, as judged from the limited information derived from an O_2–F_z montage. Periods of drowsiness and eye-movement artifacts were eliminated from the analysis.

The mean energy content (MEC) for all subjects decreased from 85[3]) (standard deviation [SD] = 19, range 58–112) at T_1 (pre-drug), to 53 (SD = 16, range 34–82) at drug peak, 90 minutes after ingestion of psilocybin (T_2). The decrease occurred in all subjects and could be easily recognized in most of them by inspection of their EEG records. The drug-induced (T_2–T_1) difference in MEC for all subjects is significant ($t = 3.98$, $p < 0.01$) (see Table).

Latency of the alpha attenuation response for all subjects decreased significantly from 0.150 seconds at T_1, to 0.118 seconds at T_2 ($t = 2.62$, $p < 0.01$).

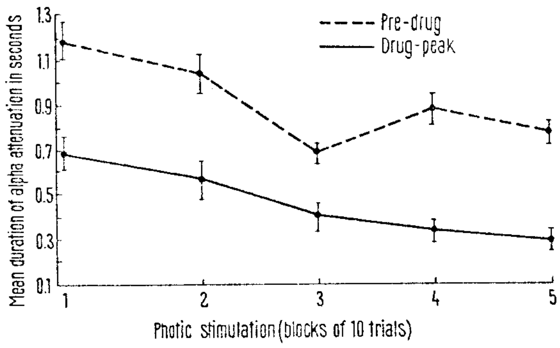

Figure 1
Alpha-attenuation (habituation) curves for 50 successive light-flashes (blocks of ten) under pre-drug conditions and 90 minutes after the ingestion of 160 µg/kg psilocybin (drug peak). Each point represents the mean of ten trials for eleven subjects.

The mean duration of alpha attenuation at T_2 for all subjects decreased significantly under the influence of psilocybin from 0.992 seconds (SD = 0.264, range 0.5–1.42) to 0.674 seconds (SD = 0.359, range 0.895–1.15) ($t = 7.38$, $p < 0.01$). A progressive decrease in duration of the alpha attenuation response (increased habituation) was observed with each block of 10 trials from T_1 to T_2 [11], with the slopes of the curves for the control and drug periods being identical (see Fig. 1).

Reaction time was significantly longer during alpha activity (eye closed) than without alpha activity (eyes open) ($t = 2.19$, $p < 0.05$), and increased significantly under the influence of psilocybin (eyes closed: $t = 1.74$, $p < 0.05$; eyes open: $t = 2.44$, $p < 0.05$).

Although the coefficient of variation (CV) for all subjects increased from the control value of 16[3]) at T_1 (SD = 7, range 6–28) to 20 at T_2 (SD = 8, range 5–30), the change was statistically not significant ($t = 1.65$, $p > 0.05$) (see Table).

(2) *Intra-group results:* MBTI extraverts display higher mean energy content (MEC) than introverts under no-drug conditions (T_1) and show a greater decrease in MEC at T_2 than the introverts (see Fig. 2). The interaction is significant by an analysis of variance[4]) ($F = 12.92$, $p < 0.01$).

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[3]) A value well within the 'normal' range.

[4]) All analyses of variance in this paper are two-way with one repeated measure. The 'unweighted means' solution was used because of unequal group sizes [12].

* This sign denotes an expression described in the Glossary.

Volunteers	Mean energy content (MEC) T_1	T_2	Coefficient of variation (CV) T_1	T_2
J.G.	112.6	77.2	5.7	5.2
P.S.	81.4	46.5	27.8	25.4
B.M.	108.0	42.4	8.3	28.0
W.K.	85.3	82.6	13.3	6.4
L.C.	59.4	45.4	27.0	24.2
S.S.	102.4	39.9	15.0	29.2
R.S.	58.1	54.8	16.1	19.3
Y.F.	98.0	53.8	12.8	23.4
S.D.	89.1	68.5	20.8	19.5
R.M.	67.9	34.0	13.0	17.4
J.D.	75.5	36.7	15.8	21.6
	$\bar{x} = 85.2$ $\sigma = 18.9$	$\bar{x} = 52.9$ $\sigma = 16.5$	$\bar{x} = 15.9$ $\sigma = 6.9$	$\bar{x} = 19.9$ $\sigma = 7.9$

Influence of 160 μg/kg psilocybin on the mean energy content (MEC) and coefficient of variation (CV) of the EEG in eleven college-age volunteers. Whereas each subject's MEC is decreased by the drug (at T_2), with the overall decrease being significant ($t = 3.98, p < 0.01$), the slight drug-induced group increase in CV is not significant.

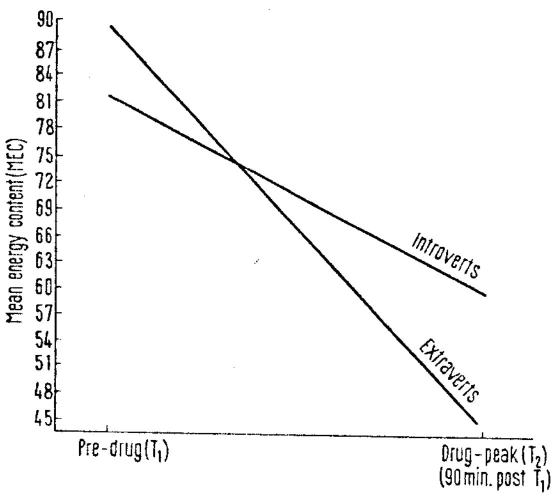

Figure 2
Influence of 160 μg/kg psilocybin on the mean energy content (MEC) of alpha activity in Myers-Briggs Type Indicator (MBTI) introvert and extravert subjects. The significantly different responses of introverts and extraverts ($F = 12.92$, $p < 0.01$) illustrate a personality-dependence of drug response. Note that the drug-induced (T_2-T_1) change in extraverts is greater than that of introverts, a phenomenon we have consistently observed that is probably related to the extravert's lower levels of cortical arousal without drugs (T_1) [21].

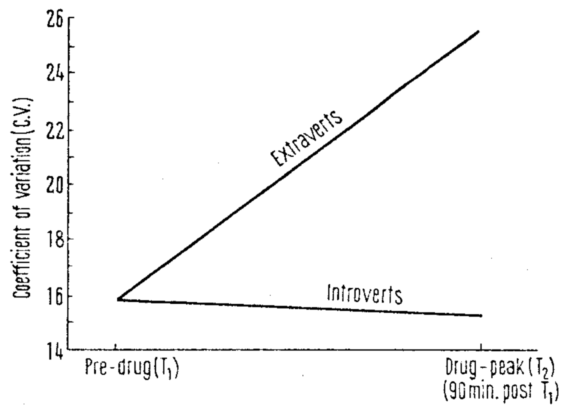

Figure 3
Influence of 160 μg/kg psilocybin on the coefficient of variation (CV) of alpha activity in MBTI introverts and extraverts. Extraverts react to the drug with significantly greater changes in CV than introverts ($F = 7.00$, $p < 0.05$), a pattern probably related to their lower level of cortical arousal at T_1 [21].

Although the coefficient of variation at T_1 was identical for both introverts and extraverts, the latter show a definite increase at T_2, while introverts remain essentially unchanged (see Fig. 3). The interaction is significant beyond 0.05 ($F = 7.00$).

There is at T_1 a significant positive correlation between length of reaction time and introversion ($r = 0.741$, $N = 11$, $p < 0.01$) for eyes closed, and a nearly significant correlation with eyes open ($r = 0.508$, $N = 11$, $p > 0.05$).

There is also a significant difference between MBTI perceivers and judgers in terms of their reaction times at T_1. Perceivers have faster reaction times than judgers (Spearman Rank-Order Correlation $r_s = -0.830$, $p < 0.01$ with eyes open), a personality trait-dependent difference which disappears under the influence of psilocybin at T_2. Incidentally, there is in our sample an association between the MBTI personality traits of perception and extraversion, and between judging and introversion ($r = -0.551$, $p < 0.05$).

When we define creativity in terms of the MacKinnon creativity measure, which sums the intuition (N) and perception (P) scores on the Myers-Briggs Type Indicator, our more creative subjects display significantly shorter reaction times at T_1 than our less creative subjects ($r_s = -0.613$, $p < 0.05$ with eyes closed; $r_s = -0.613$, $p < 0.05$ with eyes open). Whereas both groups display an increase (but not a significant one) in coefficient of variation from T_1 to T_2, the CV of the more creative subjects is higher both at T_1 and T_2 (at T_1: $r = 0.503$, $p < 0.05$; at T_2: $r = 0.569$, $p < 0.05$).

Subjects with large handwriting area at T_1 displayed significantly faster reaction times at T_1 than those with small handwriting area ($r = -0.716$, $p < 0.01$ with eyes closed; $r = -0.551$, $p < 0.05$ with eyes open). However, the superior performance (shorter reaction time) of this group with large handwriting area disappears under the impact of psilocybin (at T_2), and their reaction time is then practically the same as that of the smaller handwriting-area group (see Fig. 4).

Subjects with large handwriting area at T_1 again display a longer latency prior to alpha blocking under the influence of psilocybin than those with small handwriting area ($r = 0.808$, $p < 0.01$).

Handwriting area itself is personality trait-dependent: MBTI judgers display a significantly smaller handwriting area than perceivers ($r = 0.758$, $p < 0.01$), a difference which disappears under the impact of psilocybin.

A drug-dependent difference in reaction time becomes apparent when related to another handwriting parameter, average force (pressure) over time. While the reaction time of subjects with small and large average handwriting force is essentially identical at T_1, psilocybin significantly increases the reaction time in only those

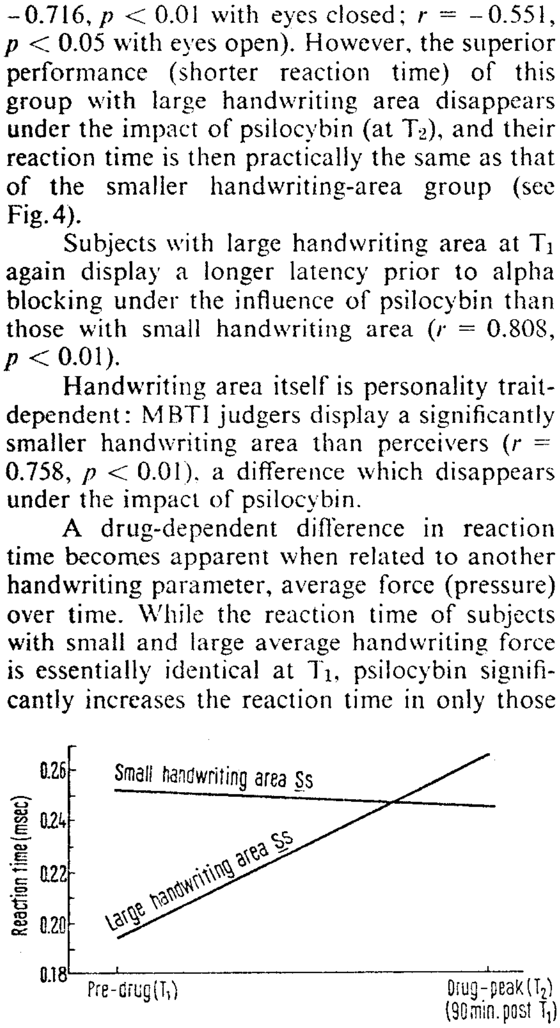

Figure 4
Influence of 160 μg/kg psilocybin on reaction time in subjects with small and large handwriting area at T_1. Note that reaction time deteriorates under hallucinogenic drug influence only in subjects with large handwriting area, who had significantly faster reaction times to begin with (at T_1) ($r = -0.716$, $p < 0.01$ with eyes closed; $r = -0.551$, $p < 0.05$ with eyes open), whereas reaction time is unaffected or even slightly improved by the drug in subjects with small handwriting area. There is no significant difference in reaction time between the two groups at drug peak (T_2).

subjects with small average force ($F = 7.29$, $p < 0.05$).

Whereas the group with large handwriting force and that with small force display an increase (but not a significant one) in coefficient of variation from T_1 to T_2, the coefficient of variation of the group with the larger force is higher both at T_1 and T_2 ($F = 9.22$, $p < 0.05$).

Lastly, there is no significant difference between the length of reaction times *at T_1* for stable and variable subjects (displaying small and large standard deviations, respectively, on the area of their handwriting, SDHA [10]). But under the influence of a hallucinogenic drug like psilocybin, the reaction time of only the variable subjects is lengthened while the reaction time of stable subjects is essentially unaffected.

These results suggest that subjects with certain traits are substantially more affected by the drug psilocybin: extraverts and subjects with high MacKinnon creativity scores, large handwriting area, large standard deviations on the handwriting areas, and small average handwriting force all display lengthened reaction times at the peak of the drug experience. Could it be that all these traits reflect a particular type of subject, who reacts in a characteristic manner not just with respect to reaction time? If so, one would expect most of these traits to intercorrelate and, indeed, this is the case: more creative people, for example, have larger handwriting areas and larger standard deviations on handwriting area than less creative people ($r = 0.527$, $p < 0.05$; $r_s = 0.573$, $p < 0.05$, respectively).

(3) *Intercorrelations:* (a) The longer the reaction time (with eyes closed) the shorter the latency of alpha attenuation at T_1 and at T_2 ($r = -0.607$, $p < 0.05$; $r = -0.564$, $p < 0.05$, respectively). (b) The shorter the reaction time (with eyes open) the longer the alpha attenuation at T_1 ($r = -0.546$, $p < 0.05$). (c) The longer the reaction time the higher the MEC at T_2 ($r = 0.627$, $p < 0.05$).

Discussion

The most important result of our pilot study is that certain changes elicited by hallucinogenic drugs such as psilocybin are personality-trait-dependent. Specifically, reaction time, and the CV as well as MEC change in both direction and extent as a function of personality type (Fig. 2 and 3).

We have reproduced GOLDSTEIN's LSD-induced decrease in MEC by using psilocybin, and have further refined this finding by showing that the extraverts of the group contributed significantly more to the decrease than introverts. This personality trait-dependent response is even more evident in relation to the CV. While GOLDSTEIN found an LSD-induced decrease in CV using 'reformatory volunteers' as controls, we find a slight overall increase in our college-age volunteer control group[5]). This increase, however, is produced by the extraverts of our group whose psilocybin-induced increase is significantly higher than that of the introverts, whose CV's under the hallucinogenic drug remained basically unchanged.

The disparity in drug-induced change in CV between GOLDSTEIN'S and our subjects may be due to the fact that GOLDSTEIN'S control group consisted of 'reformatory volunteers'. He justified this on the basis of the similarity under no-drug conditions between the spontaneous EEG's of the reformatory volunteers and those of staff volunteers. Our observations show that already-existing personality characteristics become exaggerated under drug-induced arousal, as Figure 2 illustrates. In light of the very recent findings of LINDNER et al. [13, 14], who showed that 'simple' (reasonably non-aggressive) sociopaths respond with a significantly greater autonomic increase to a catecholamine stimulus than normals, GOLDSTEIN'S reformatory volunteers cannot be considered a normal control group. Apparently, the CV's of GOLDSTEIN'S reformatory volunteers increase under LSD just as the autonomic response to an injection of epinephrine is greater in the group of 'simple' sociopaths, who have been identified as a group in need of stimulation [14].

Incidentally, it should be noted that the data of LANSING, SCHWARTZ and LINDSLEY [15] agree with our finding that reaction time under no-drug conditions becomes significantly longer with alpha activity than without.

In spite of the small number of subjects in this study, a particular type of volunteer emerges with a certain cluster of traits such as MBTI extraversion, perception and a high MacKinnon creativity score, large handwriting area, fast reaction time and a *large standard deviation* on the handwriting area. These *variable* subjects are more affected by drugs such as psilocybin than *stable* subjects with a *small* standard deviation on their (small) handwriting area[6]), with a low MacKinnon creativity score and MBTI personality traits of introversion and judging.

Finally, it becomes evident that the widely-held generalization that hallucinogenic drugs impair performance (see, for instance, reference [20]) cannot be maintained. Hallucinogenic drugs can impair a particular performance in certain subjects, but may improve the same performance in others. Moreover, certain interindividual differences may disappear under drug influence, or become manifest only in response to the drugs.

Glossary

- *Alpha attenuation* response is the diminution or disappearance of alpha activity in response to a photic stimulus.
- *Area of handwriting* (see *Methods*) is determined since, in 14 out of 16 cases, it increases under hallucinogenic drug-induced arousal [10, 19, 22].
- *Coefficient of variation* (CV) is the standard deviation of mean energy content (MEC) divided by the MEC and multiplied by 100.
- *Drohocki integrator* is a device which transforms electrical energy of the EEG into a number of pulses reflecting the amount of electrical energy in the input signal during an interval.
- *Ergotropic arousal* denotes, according to Hess, behaviour patterns that are preparatory for positive action characterized by increased sympathetic activity and an activated psychic state.
- *Force of handwriting* is personality trait-dependent: it decreases in MBTI perceivers and increases in MBTI judgers under hallucinogenic drug-induced arousal [6, 7, 10].
- *Latency of alpha attenuation* response is the time from photic stimulus to the onset of alpha attenuation.
- *MacKinnon creativity score* is obtained by summing the intuition (N) and perception (P) [Σ (N + P)] scores of the MBTI [8, 9].
- *Mean energy content* (MEC) is the average amplitude of electrical brain activity expressed in pulses per 20-second period (see 'Drohocki integrator').
- *Myers-Briggs Type Indicator* (MBTI) is a self-reporting inventory with continous scores on four scales of dichotomous Jungian personality types: Extraversion-Introversion (E-I), Sensation-Intuition (S-N), Thinking-Feeling (T-F), and Judging-Perceiving (J-P) [23].
- *Reaction time* is the time from photic stimulus to the signal produced by the subject pushing a button.

[5]) A small methodological difference in the placement of electrodes should be mentioned: GOLDSTEIN used monopolar derivation, occipital to both ears, while we used a bipolar setting between occipital and frontal.

[6]) The determination of stability or variability on the basis of a subject's standard deviations of repeated measurements of his handwriting area is only the simplest and most convenient method. We have found that a stable or variable subject will also display small or large standard deviations, respectively, on a yet-unlimited variety of perceptual and even behavioral tasks [6–8, 16–19].

standard deviation (SD) on the handwriting area at T_1 is, for a particular day, a reliable predictor of the direction and extent of hallucinogenic drug-induced or naturally occurring perceptual-behavioral change [6, 7, 10, 19].

Acknowledgments

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