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CONSCIENCE – THE CEREBRAL PROCESS

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A large debate about Conscience began in philosophy since antiquity, got an ample development in the Middle Ages and is still debated by modern philosophy. There are more than 400 definitions of Conscience. But an objective examination of Conscience, in terms of its generator cerebral functions, is still missing.

Examining the mental disorders occurring in 100 patients with cortical epileptic foci we drew the conclusion that the constantly affected area of the mind in case of Frontal Lobes (FLs) damage was Conscience. We defined Conscience as the highest spiritual level of the mind, “deciding if a given action must be, may be, or deserves to be done”. The complexity of this function supposes the coordination of a multitude of previous processes, intervening in the way to action, such as judgment, insight and decision taking, as well as the acceptance of some individual reference scales concerning human values (moral, social, ideal).

The goal of our investigation was to check the relations between mind/conscience and the cerebral cortex physical function. Taking account of the relations existing between Conscience and Judgment, we made efforts to find adequate electrophysiological ways for testing them by tasks not involving memory (3,5) or psychomotor correlates. So, we used an EEG Mapping investigation, in normal and pathologic subjects, for detecting the peculiarities of the cortical function involved.

METHODS

Subjects: Included in this study were 35 subjects, aged between 18 and 60 years, males and females. Ten of them were normal persons, without

antecedents of cerebral pathology, 25 presented various degrees of cerebral pathology, affecting FLs function. All were right handed and had at least 12 years scholarship.

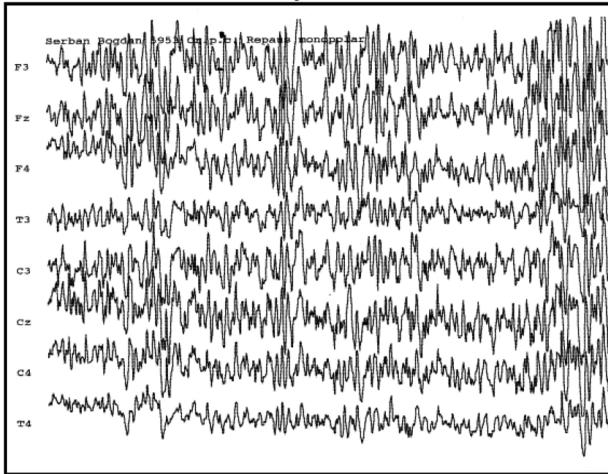
Psychological testing: Our endeavor was meant to find psychological tasks that avoid the working memory paradigm (the delayed A non B task, with previous exposure of the situation), as well as the involvement of motor responses.

For the rational type of judgment we utilized a set of 15 proverbs implying some degree of difficulty. E.g.: “Hell is paved with good intentions”. Subjects were asked to give their own interpretation of the proverbs, after ten seconds of thinking. An evaluation of response correctness was eventually transformed in a global score.

For testing the emotional judgment, based mainly on feelings and personal trends, we employed the presentation of 10 paintings, selected to be different in structure (colors and style). The subject was asked to observe the pictures simultaneously during one minute, and to choose one picture they liked and one picture disliked. The task could also give some rough information about the personality trends of the subject.

Electrophysiological investigation: Our study of cerebral electrical activity was performed using an EEG investigation on 19 channels (the 10-20 International System), with left ear reference (electrodes impedance round 5 K Ohms). Subjects were comfortably laid on a sofa, in a quiet environment. The EEG recording was performed first at rest, with the eyes closed, during 3 minutes. In the second stage a similar EEG recording was performed during one of the two described tasks (proverbs hearing, painting inspection, in different days). The

MONOPOLAR RECORDING



SOURCE DERIVATION

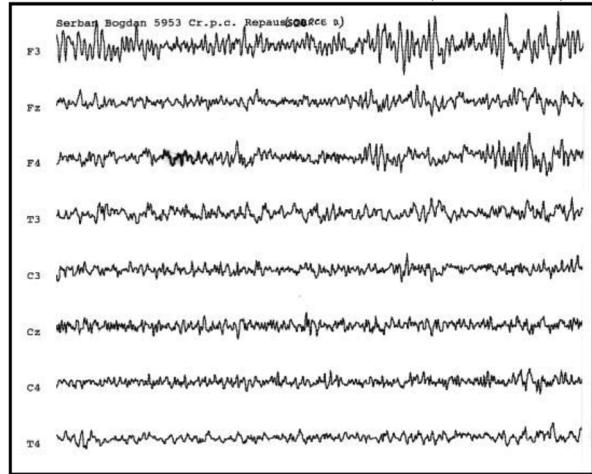


FIGURE 1. Effects of Source Derivation Filtering on the topographic differentiation of EEG rhythms. The recording is presented before and after filtration. This procedure improves the resolution of the EEG Power Mapping (at rest or on stimulation), as well as the Evoked Potentials Mapping quality. Calibration: Amplitude 50 $\mu\text{V}/\text{cm}$; Time Constant 0.3, Low pass filter 70 Hz. Sampling rate: 256 Hz.

EEG recording was stopped before asking the subject to give a response to the ongoing task.

All subsequent mathematical processing was done using a Pentium PC and an EEG Mapping program created in the laboratory. This software package includes a lot of changes which allow a plotting of clear EEG Maps, both in resting conditions and on application of the tests. The main improvement we inserted was the “Source Derivation Filtering”. The EEG recording in mono-polar paradigms is overwhelmingly contaminated by horizontal current diffusion. The total current energy in a biological tissue is of two kinds: 1) the primary, active current, induced by the ionic flow between intra and extra-cellular spaces, 2) the volume (field) current, representing the dynamic response of the media. It is said that only 10% of this current penetrates directly the scalp; 90% of it suffers a horizontal diffusion. Our procedure for the elimination of volume conducted currents (deblurring) was based on an autoregressive model. From the electrical activity power of each source, calculated after Fourier analysis, we extracted the weighted mean power of the 4-5 nearest electrical sources. Once this contamination excluded, one could find the true local EEG power magnitude. Our expertise demonstrated the good resolution of this investigation and the fact that each source cumulates the surface cortical activity and the deep electrical activity of the brain, projected on a vertical/radial vector. A supplementary facility permits a full artifact rejection. The

transformation obtained in the EEG tracings by this procedure is presented in the first Figure.

The “functional” EEG mapping procedure that we then described, called the “EEG Spectral Reaction Mapping” (SRM) performed comparative EEG power evaluations (%) in different conditions and permitted to localize the effects of a given functional task on the EEG activity. The procedure was successfully used in order to evidence the cerebral effects of visual, auditory, verbal, motor, lexical stimulation and so on (6,8,10).

In this study we used SRM to assess the cerebral electrical activity changes induced by mental judgment testing. Changes in EEG power are appreciated per cent; the available reference scales on 11 steps measuring reaction intensity. On these scales the percentage of 100 % (colored in blue) indicates the topographic cortical areas characterized by no EEG change. Increases in these percentages (colored in green, yellow, orange, red) indicate the enhancement in power of a given cerebral electrical activity (delta, theta, alpha and beta) during the imposed psychological testing; decreases were also observed. Statistical analysis was further made by plotting Grand Average (group) Maps, or t-significance Maps.

RESULTS

a) EEG Mapping normal reactions to judgment testing

Figure 2 presents two Group Average Maps obtained by summing the EEG effects of the two

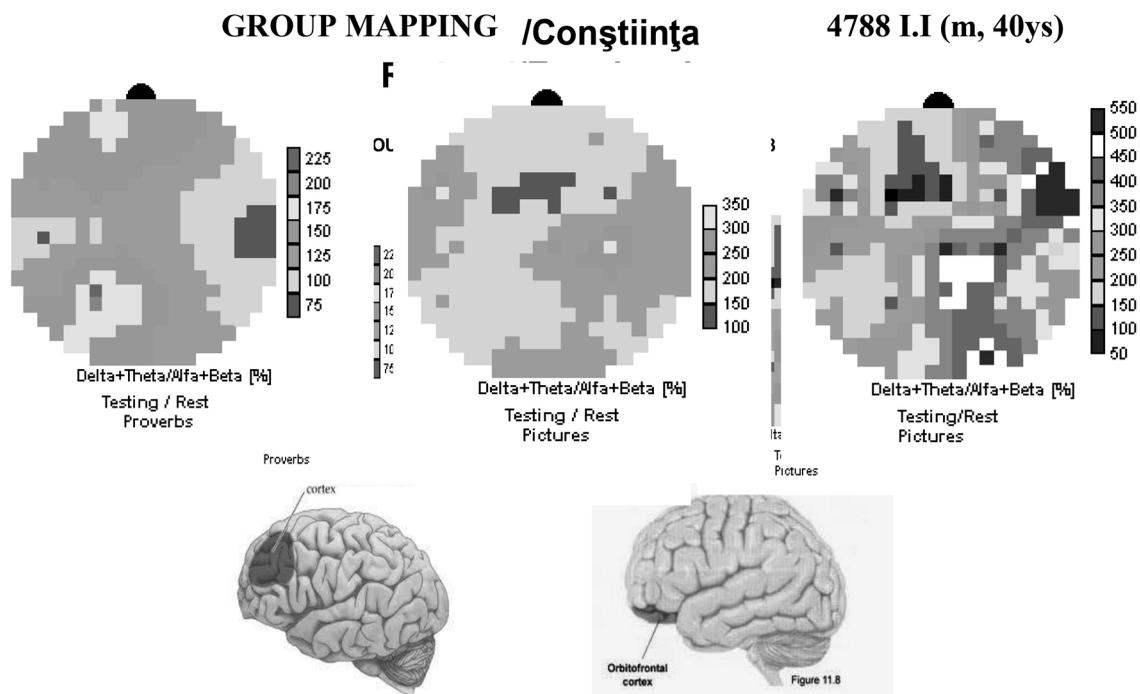


FIGURE 2. EEG Spectral Reaction Mapping in rational (proverbs) and emotional (painting) Judgment. On the left: group Maps, on the right an individual Map.

types of Judgment, already mentioned in the old antique philosophy, the rational and the emotional judgment, in 10 normal subjects. These are Spectral Reaction Maps (testing versus rest power ratio mapping). One can easily observe that there are differences between the two functional patterns.

The reaction to standard proverbs testing (left) involved only the left hemisphere. The EEG activation consists in an increase of the Delta-Theta /Alpha-Beta power ratio by 225% in the intellectual Wernicke area. This activation results from the individual efforts to understand and give possible solutions to the proverb statements. Then, there is a propagation of excitation, and a 175% average activation of the left dorsal prefrontal area, where probably the solution selection (rational judgment) must be performed. In this case Broca area is not involved, because recordings are taken in the pre-response period (Fig. 2).

The non-rational (emotional) judgment (right) was tested by the visual choice of liked or disliked images, among 10 paintings. EEG activation in this situation involved mainly the right hemisphere. An obvious activation of the right occipital lobe, is propagated to the right parietal area (mediating visual understanding} and to both orbital areas.

The image of emotional EEG activation obtained in a single highly responsive subject allows a better

analysis of the process. It can be seen that, in case of paintings choice, the primary activation is “attracted” in the right occipital-parietal area; then there is a bifurcation of excited pathways, possibly sub-cortical, from the medial posterior parietal area to both orbital frontal fields. Taking account of the fact that Source Derivation also reveals radial vectors of deep generators, this activation centered in the lateral pF1-F7 and pF2-F8 region must reflect the functional status of the basal/orbital FLs. The astonishing opposite (inhibitory) EEG reaction observed in the left dorsal FL area, mediating rational judgment (a decrease in the Delta-Theta/Alpha-Beta ratio), suggests a functional antagonism between the two judgment areas.

It is, moreover possible that each of the two basal-lateral frontal areas has its specific psychic contribution, as indicated by our investigation of mentally disturbed patients. The FL functional contribution to judgment is obvious, in the absence of any operant memory involvement.

b) Pathological responses demonstrated by EEG Mapping in cases with FL damage

In Fig. 3, individual responses to the proverb interpretation task and the effects of pathology on the corresponding Spectral Reaction EEG images are illustrated. The idea was to find whether FL function and judgment are indeed connected.

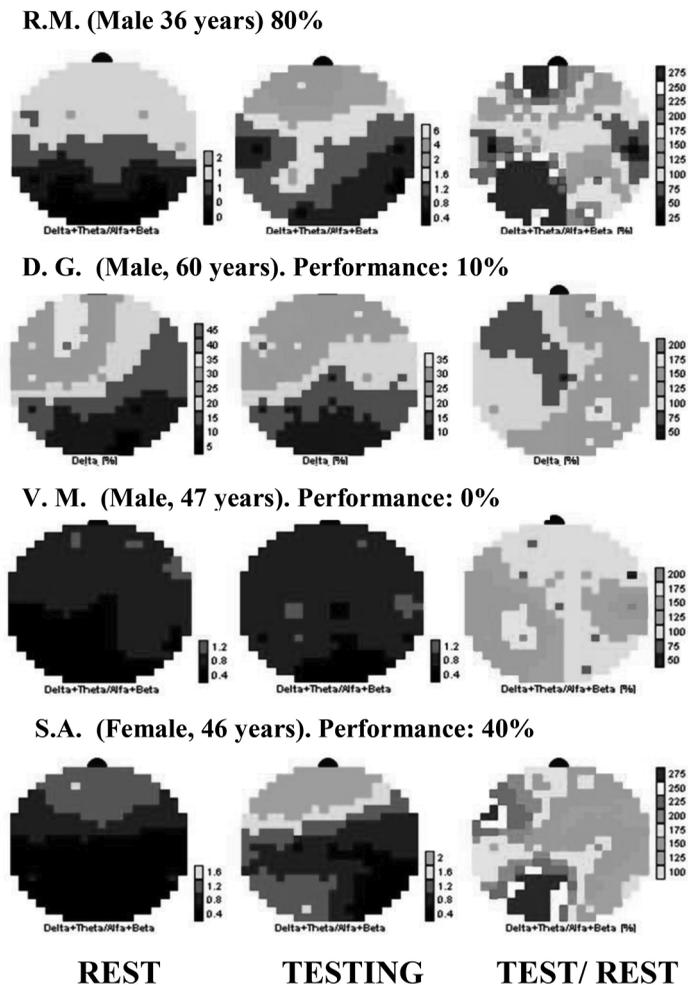


FIGURE 3. EEG Mapping of rational Judgment Testing (proverbs interpretation) in pathological conditions. Cases: R.M. – headaches; .D.G. – extirpated left FL tumor; V.M. and S.A. – Epilepsy. For explanations see text.

On 25 neurological patients we investigated with the same tasks the EEG effects of rational and emotional judgment. In the Figure, maps at rest, during testing, and reaction maps (%) are presented.

Subject R.M. (male, 36 years) although complaining of headaches, for which he was addressed, succeeded to give a significant number of correct responses in proverbs testing (80%). His EEG Mapping at rest shows a diffuse slight increase of Delta-Theta/ Alpha-Beta power ratio (0.4-2). The map obtained during testing shows instead a clear-cut normal activation of the left Wernicke, propagated to the left prefrontal area. The Spectral Reaction Map demonstrates the strong increase (275 %) of the ratio in the left parietal and prefrontal cortex, on testing versus rest (the two activation areas involved in intellectual and judgment performance).

Subject D.G. (male, 60 years), suffered 6 years earlier the surgical removal of a left FL tumor. He

presented since three grand mal seizures, but his neurological status was considered to be normal. The EEG Mapping at rest reveals a severe spontaneous abnormality of the left FL area activity (Delta partial power up to 45%), that persisted during proverbs testing. His task performance was overtly low (10%). The Spectral Reaction Mapping (Testing versus Rest EEG powers comparison) reveals a remarkable compensatory activation of the right hemisphere, occurring both in the right prefrontal (200%) and the right parietal area (200%). This evident functional transfer could not compensate, however, the psychological deficit of rational judgment manifested by the patient.

Subject V.M. (male, 47 years) was an epileptic presenting approximately two tonic clonic seizures per month (treated with Phenobarbital and Carbamazepine). His EEG Mapping at rest is not seriously affected (Delta Theta/Alpha Beta ratio: 0.4-1.2). He reported Short Term Memory deficits, but had

also an extremely poor performance on the proverbs interpretation task (0%). When asked to answer, he repeated obstinately the proverbs “ad literam”. The EEG Spectral Reaction Mapping shows a correct activation of the left Wernicke area (200%), but totally absent electrical activation of the dorsal FLs (100%, i.e. no EEG response on testing versus rest). One can see, instead, an abnormally high activation of the right temporal lobe (200%).

Subject S.A. (female, 46 years) also reported spells since several years, this time accompanied by manifestations of vegetative character: gastric pain, suffocation, associated with anxiety, eventually fainting (without convulsions). His performance in the proverb interpretation task was of only 40%. His EEG Mapping image at rest looks normal (Delta-Theta/Alpha-Beta ratio: 0.4-1.2). On the judgment testing the Spectral Reaction Map shows a strong activation of the left Wernicke area (275%) but sensory inflow deviation from its normal course to the left dorsal to the lateral-basal (orbital) area of the left FL. In such cases we ordinarily suppose the existence of a focal hyperexcitability, which is at the origin of the generated spells. The abnormal excitability (common in epileptics) creates in this case an attraction of the normal flux of information during judgement to basal FL areas. One may presume that in such conditions judgment becomes prevalently emotional, which explains the diminished rational performance score of our patient.

These cases denote the complexity of mental activity disorders occurring in pathology, but also the possibility to better understand them by EEG Mapping.

COMMENTS

The existence of two types of judgment (rational, emotional), already mentioned in antiquity, was confirmed by this investigation; it shows that the functional dichotomy is mediated by the existence of two separate associative areas in the FLs. The first expresses the objective reason (the “Free thinking”), the second a subjective reason (the “Free will”). The FL structures are activated by such mental processes, independently of the previously sustained (3,5) STM or Drive correlates.

These experiments demonstrated also that our technology of EEG Mapping is extremely efficient

in the detection of cerebral activity localized changes, superior to many of the software packages existing in the laboratory international practice.

Role of the FLs in mental activity

In our opinion Conscience uses these two types of judgment in order to decide that a given action must, may or deserves to be done. There are several brain structures which prepare action (the coordinated activation of the motor centers) in response to a life demand. In straight cooperation, the FL centers decide “what” has to be done, the limbic structures (Hippocampus, as generator of psychomotor initiative) “when”, and the Parietal associative areas (site of intellectual activity) “how” an action must be done. When one of these two FL areas decide an action, this action has effects, and the effects have consequences (good or bad). A feedback, signaling the effects and consequences of our deeds in the outside world, returns in our brain (is recycled) and is once more processed by the FL areas, contributing to Judgment. This is the way in which “Conscience” occurs as an “a posteriori” judgment, appreciating our own previous behavior. This recycling gives rise to psychological consequences such as remorse, guilt, or of joy, satisfaction when they involve the basal orbital areas. Sent to the dorsal FL rational judgment area, a wrong strategy can be changed. Unfortunately this process is inadequately slow (it includes doubt). Shakespeare complains what happens when an individual (Hamlet) has too much rational conscience: “Thus, conscience does make cowards of us all”... In fact, as Erasmus complained, we are confronted with a diminished rational conscience, due the overwhelming predominance of the irrational (passional) type of human behavioral response. According to Messulam, “the socially appropriate comportment and moral conduct are dependent on the ability to transcend an egocentric point of view“, in other words, to pass from the unique emotional judgment, to rational judgment. This hoped even Aristotle and Plato, promoting virtue. Our experiments showed that the two types of selection/choice and decision taking, are actually opposite.

Pathological cases exam confirmed this interpretation. When the left prefrontal cortex was damaged by a tumor (case D.G.), the normal left EEG reaction to proverbs was absent, and the test perfor-

mance was concomitantly low, in spite of the appearance of a compensatory activation in the right prefrontal area. An activation of the left, intellectual, Wernicke area always goes to the left dorso-lateral pre-frontal area of rational judgment; the activation of the right associative (intuitive) parietal areas sends their output to the emotional, basal-orbital FL areas. Testing the Spectral Reaction to an Area of Bach by EEG Mapping, we found only once a characteristic activation in the right prefrontal area (in a musically trained subject). In patients with Epilepsy (V.M. and S.A) the increased excitability of the epileptic foci (either temporal or frontal-orbital) may induce a deviation of functional activation from the left prefrontal area; in such conditions the response of the dorsal FL was considerably reduced, and the performance in proverb testing diminished, although the activation of the left posterior (parietal) association field continued to be strong. This may explain the “Phineas Gage dilemma” regarding the destruction of the FLs: the intact persistence of cognition and intelligence in such patients. The functional disorders in FL disturb only judgment and conscience. The attempt of Damasio to ascribe morality to the FLs function is not satisfactory. In our opinion morality is not a brain function, but a reference scale, different from one individual to another. Moreover, the FL mechanisms do not decide only about ethic issues (right and wrong), but also about esthetic (beautiful-ugly), axiological (value-non-value), cognitive (true-false), and other bipolar qualia issues.

In our opinion, the differences between the two types of judgment may depend on the particular cyto-architectonics of the FL processors involved (Brodmann areas 7, 19, 20). The prefrontal dorso-lateral area is one of the latest achievements in brain development; it is a neo-neocortical area. The structure of this exclusively granular associative cortex is particular, presenting a tendency to loose columnar organization; neurons are disposed in six layers, successive connections being formed (each

neuron sends connections to other 5000 neurons). This particular arrangement can sustain a heuristic type of judgment: gradual binary yes/no selection resulting in progressively refined solutions. This type of judgment is relatively slow and accompanied by doubt (deliberative). The orbital FL cortex is much more primitive. It is non-granular or dys-granular, has only three layers with lower cellular density, strong afferent connections with emotional (feeling) centers, like the amygdala and the hypothalamus, bringing hot information from the body, and a pyramidal layer strongly connected with the Supplementary Motor Area (anterior g. Cinguli). It includes many great size (Von Economo) cells, which are possibly implicated, in a special type of memory (the memory of ideas accumulated during life, either by education or by personal experience). Such ideas, sometimes induced by suggestion, are extremely stiff. When decision taking is performed by this area, it has a possible stochastic mechanism, based on innate (ideals, desires) or acquired algorithms (myths, ideology). It is strongly motivated, prompt, expresses the self, the free will, and has a high degree of certitude for the individual (according to Gazzaniga, the Self is ascribable to the conceptualizer left hemisphere).

These types of judgment have both drawbacks and qualities. The conscience problems they generate may be extremely disturbing for the individual. The patients with dorso-lateral FL dysfunction show lack of self control, inertia, lack of responsibility. The patients with orbital FL dysfunction loose mental flexibility, their behavior becomes compulsive, stereotyped, egocentric (lack of empathy), they often manifest delusions (of guilt or pursuit), have a tendency to fanaticism, excessive religiosity, they do not understand social constraints, are able to aggression, even murder (7).

We believe that this approach of FLs function is favorable to further research of brain-mind interaction and of mental diseases. We found significant functional alteration in these areas both in psychopathic and psychotic (dementia) patients.

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