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Basic symptoms and cognitive dynamic disorders in schizophrenic patients*

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Summary

Using a new scientific paradigm, chaotic-deterministic dynamics, our research group developed a new cognitive instrument which is administered by means of a computer: the Test of Random Rhythm Generation (ARG). Theoretical background and preliminary results in two young male, defectual schizophrenic patients (paranoid type) are here presented. Basic symptoms were explored by means of the Frankfurt Complaint Questionnaire of FBF (*Frankfurter Beschwerde-Fragebogen*) and the Bonn Scale for the Assessment of Basic Symptoms of Gross et al. Possible relationships between cerebral complexity and basic symptoms are discussed. It is concluded that the ARG is a valuable technique to measure the patient's cognitive potential as well as his complexity level (or cerebral chaotic dynamic complexity). Finally, it is hypothesized that defectual psychotic patients generate more rigid and rhythmic series than control groups. Further work must be done in this new research field.

Key words: basic symptoms, cognitive disorders, schizophrenia.

Introduction

In neurobiologic research, the identification of specific mental functions seems nowadays to be necessary. Accordingly, some explorations collecting general dynamic characteristics, but not always specific symptoms, must be found. A dynamic characteristic of this kind can be called general "cognitive potential" and might be identical to the classic stage of "central stimulation" described by Pavlov. This "cognitive potential" means the capacity, both in volume and accuracy, for the information processing in a given moment. According to Huber's theory about basic symptoms [10], disorders at this level are placed at the transphenomenal level and close to the neurobiological substratum.

In consequence, scales designed to identify these basic symptoms would be also suitable to collect their cognitive aspects. Effectively, it has been suggested that the Frankfurt Complaint Questionnaire of Süllwold expresses the psychological deficit in the information processing experienced by the patient [19]. However, objective tests, if possible administered by means of a computer, seem to provide some light to this point. In this paper we present our first results with a new cognitive instrument called the "Test of Random Rhythm Generation" (ARG) which has been developed in our research group using a new scientific paradigm: chaotic-deterministic dynamics. The test can be directly requested to the authors and its copy-right is protected by the University of Valladolid (Spain). The objective of this paper is to present the characteristics of the test and some preliminary results, as well as to discuss its possible relationships with scales assessing basic symptoms. Nevertheless, first it all it seems necessary to briefly summarize main postulates of the above-mentioned new paradigm.

Chaotic-deterministic dynamics

As already mentioned, we have tried to identify and measure the "cognitive potential" of the cerebral dynamics. Classic ideas about homeostasis and cybernetic self-control dating from the beginning of the century have already been overcome. The development of chronobiology by the group of Halberg showed that fluctuating and rhythmic systems appeared everywhere, for example in blood pressure [9]. Nevertheless, aperiodic series frequently existed instead of rhythms. The more accuarate, continued and frequent measurements, the more aperiodicity seemed to be found.

Natural systems in general, and living organisms in particular, consist of a great number of systems; so they deserve the name of complex systems. They also obey to a nonlinear dynamics, that is, they respond to the application of a stimulus in a nonproportional way. Accordingly, in complex systems the study of the nonlinear dynamics in a situation far away from equilibrium represents a new scienfic-theoretical paradigm [14, 15]. In summary, instead of self-control, we should look for self-organization; instead of rhythmicity, random fluctuation into certain limits (deterministic chaos), and instead of regulation and homeostasis, chaotic trajectories which are defined by the so-called "attractor". This attractor may be represented in the phase space. Finally, the ordinary sense of the concept "causality" should also be abandoned. We may affirm that the biological meaning of these findings is that a fluctuating and aperiodic system is more adaptable than a rigid one. It might be confirmed, for example, by the fact that a flexible personality affords variable demands of the enviroment better than a rigid one. In consequence, the capacity of generating partially random signals, in the sense of deterministic chaos, runs parallel to the biological systems' stage of health. All this knowledge may be thus applied to the study of cerebral dynamics, and consecutively to psychopathology.

Studies with the electrocardiogram

From the theoretical point of view, any signal which is produced by the biological dynamics must follow the chaotic deterministic dynamics, that is, "disordered in certain order". In other words, it is partially random and disordered or aperiodic. It also means that the signal keeps certain norms of rhythms self-resemblance along time which is typical from fractal systems. These signal characteristics can be registered in electronically digitalized signals and may be studied through mathematical analysis. The so-called attractor may also be drawn. It provides a graphic idea of the system complexity. In this way, some constants including the fractal dimension, the Lyapunov exponent and the correlation function are identified.

Based on these principles, electrocardiogram was first studied. Goldberger and coworkers [6] were able to determine that a rigid stabilization on certain rhythms indeed predicted the apperance of a fibrilation. For psychopathologists, a more important and surprising finding is the fact that dynamic dysfunctions of the electrocardiogram correlate with the mental state. The group of Sabelli in Chicago [4, 17], including Dr. Justo Díez who also collaborates in our group, has also contributed on this line. Effectively, they have described some patterns which seem to be specific for schizophrenic and deppresive patients. It is suggested that electrocardiogram reflects the general dynamic state of the organism, and may provide access to the cerebral dynamics itself.

Studies with the electroencephalogram

On the other hand, the study of the EEG under these techniques was first carried out by the group of Babloyantz, from the Institute of Nonlinear Dynamics of Brussels, directed by Prigogine. They were able to show the variety, or specifity, of fractal attractors in epileptic seizures, in several levels of consciousness, and in some organic dementias as the Kreutzfeld-Jakob disease [1, 2, 5].

In psychiatry, a considerable amount of works under these principles have appeared since then. In the group of Giessen (Germany) directed by Gallhofer, Meyer-Lindenberg has demonstrated that the rate of dynamic complexity detected in the EEG increases simultaneously with cerebral maduration [12]. Furthermore, in schizophrenic patients the more negative symptoms, the more complexity reduction. In France, Petit and Petit have also studied this problem. They found that the chaotic attractor had a different correlation dimension in schizophrenic patients compared with control subjects [13]. We have also tried to contribute to it using a new method which has been developed by our group. Only some preliminary findings are shown here.

We hypothesize that the capacity to perform tasks must be related to the cognitive potential and to the level of cerebral chaotic dynamic complexity. Creativity and accuracy in some tasks would also correlate with it. There are supposed to be other aspects of this very cognitive potential. In Sydney, Rosenberg et al. asked subjects to choose several times a number from one to ten. Numbers had to lack of a generative rule, that is, to be as random as possible. They demonstrated that generation of a random series is difficult, requires an important cognitive effort and decreases in several kinds of patients [16]. From the neurobiological and dynamic point of view, variability, chaoticity and a higher rate of freedom are the foundation of creativity. Automatisms in lower functions would allow this greater freedom in higher functions.

Methods

Patients were recruited from the Acute Unit of Psychiatry at the University Hospital of Valladolid, Spain. The Frankfurt Complaint Questionnaire of FBF *(Frankfurter Beschwerde-Fragebogen)* of Süllwold [18], and the Bonn Scale for the Assessment of Basic Symptoms of Gross et al. [7] were used to assess basic symptoms. Instructions of the authors were carefully followed. Two of us (N.J.J. and M.L.V.) performed the necessary 10 supervised interviews with an experienced user of the BSABS at the Psychiatric Clinic at the University of Aachen (Prof. J. Klosterkötter).

A new technique aiming at evaluating the subject's cognitive potential was designed based on previous considerations. It is called the "Test of Random Rhythm Generation" (ARG). Because of the newness of this test and the variety of analysis to be performed from the obtained results, only preliminary results corresponding to two schizophrenic patients will be here presented.

Patient 1

The first case is a 26-year-old single male patient. He comes from a middle-low socioeconomic level and is living with his primary family in a small village. His mother had received ambulatory psychiatric treatment because of a probable depressive picture. The patient is the eldest of 3 brothers. The youngest one is a 20-year-old male who suffers from panic attacks. The patient is defined by his mother as "hard-working and very affectionate".

The patient was admitted at our Acute Unit of Psychiatry showing an agitation episode with verbal aggresivity toward his family and neighbourhood. At the psychopathological exploration, the patient presented auditive hallucinations, paranoid delusion, influence experiences, thought control, withdrawal and blocking, as well as somatopsychic depersonalization. The picture gradually remitted when pharmacologic treatment with middle-doses of haloperidol and benzodiacepines was established.

The first admission of the patient at our Unit was five years before the present episode, although he refered experiencing basic symptoms since the previous year (at 20-year-old). At admission, he showed a picture with relevant psychomotor agitation, paranoid delusional ideation, auditive hallucinations, neologisms, influence experiences, thought control and insommnia. According to his family, his character had changed in the year before this acute episode, in relation to his moving to a 600-km.-away town because of work reasons. He became irritable, unsociable and small-communicative. He left his usual occupations, worked irregularly and slowly isolated from his environment. He was diagnosed as suffering a paranoid schizophrenia and was treated with haloperidol and chlorpromazine which caused a gradually decrease of the acute symptomathology. Since this first admission at the Hospital up to now, the patient has been ambulatory treated with neuroleptics, mainly of depot intramuscular sort. He has also presented several relapses requiring readmissions at the Unit. These are frequently associated with drug use, specially alcohol and cannabis. The initial diagnosis has remained the same. The patient has an unorganized life. He works irregularly and has a certain isolation from his environment.

Patient 2

The patient is a 31-year-old male patient. He is married and has two children. He lives with his family in a rural area and comes from a middle-low socioeconomic level. Two uncles of both paternal and maternal lines has been admitted several times at psychiatric hospitals and a younger brother has been diagnosed of paranoid schizophrenia. The patient is defined as an introvert, cheerful, sensible, hard-working and obedient person. He has always been well-integrated in his friend group. The patient was admitted at the Acute Unit of Psychiatry of the Hospital due to a drug self-intoxication which occured in the course of a psychotic depressive episode. He felt sad and had hypochondriac complaints, as well as auditive hallucinations and delusional ideation with jealous content. The picture slowly ceased with middle-doses of haloperidol used as mainly drug therapy.

He was first admitted at the Unit at 17-year-old, but he admitted suffering from basic symptoms since 13. He chiefly presented at admission irritability, unappropiated behaviour, auditive hallucinations, self-reference delusional ideas and vague hypochondriac ideas. Since then, he has suffered several psychotic relapses which are mainly associated with sporadic cannabis intake. In his readmissions at the Hospital, he has always received the diagnosis of paranoid schizophrenia. Excluding his acute episodes, the patient has an active life at personal, work and social levels. He keeps adequate relationships with his relatives and doesn't take toxic substances in these periods. Nevertheless, in the course of his illness depressive symptoms often appear. This fact has caused the addition of antidepressive drugs to the patient's treatment.

At the present admission and according to DSM-IV criteria, both patients were diagnosed of paranoid schizophrenia, course episodic with interepisode residual symptoms. In addition, both of them were identified as suffering from post-psychotic irreversible pure defect [8, 10].

As for the Test of Random Rhythm Generation, the subject is asked to press the space key of the computer as irregular as possible, till the screen shows the end of the exercise. Once the subject is placed in standard conditions of previous contact, time, light, the computer shows firstly an example of the sort of rhythms which are required. This is presented by means of a sparkling square of 4 by 4 cm. As an example, the subject must then generate two series of 64 blows. Only the third series is registered for assessment, once it has been checked the subject understands sufficiently the task to perform. The computer program records afterwards all the parameters and analyse the obtained results in the following basic aspects which are dysplayed both numerically and graphically:

1. Histogram of interval frequencies between blows.
2. Chaotic dynamic attractor of the generated series expressed in the phase space.
3. Correlation function which is graphically expressed by the logarithm of the function.

Results

Prodromal symptoms prior the first acute episode were identified in both patients: since 19 for patient 1, that is, one year before, and since 13 for patient 2 (4 years before). Basic symptoms of all subscales were detected in the two patients. As an example, tables 1 and 2 show results obtained in subscales C (cognitive disorders) and D (coenesthesias). In patient 1, 23 symptoms belonging to cognitive disorders and 8 of coenesthesias were positive, while in patient 2 the figures are 32 of cognitive disorders and again 8 of coenesthesias.

Table 3 show scores obtained by both patients in the FBF. Total score is 65 in the first patient and 26 in the second. Almost all scales are represented in the two patients. Direct scores were compared to a sample of 293 psychotic Spanish patients [11] and transformed into "percentil scores". As it has been throughly exposed [11], percentil scores may be interpreted as follows in relation to

	DOUBTFUL	YES	NO
C11		X	
C121		X	
C122		X	
C13		X	
C141			X
C142		X	
C143			X
C144			X
C145			X
C15			X
C161			X
C162			X
C17		X	
C18		X	
C19		X	
C110		X	
C111			X
C112		X	
C113		X	
C114	X		
C1151		X	
C1152			X
C116		X	
C117		X	
C211			X
C212			X
C213			X
C221			X
C222		X	
C231			X
C232			X
C233			X
C234			X
C235	X		
C236		X	
C237		X	
C238			X
C239			X
C2310	X		
C2311			X
C2312	X		
C241			X
C242			X
C251			X
C252		X	
C261		X	
C262			X
C263			X
C27			X
C28			X
C29			X
C210	X		
C2111		X	
C2112			X
C31		X	
C32		X	
C33			X
C341		X	
C342			X
C35	X		
D1			X
D11		X	
D2		X	
D3		X	
D4	X		
D5		X	
D6			X
D7		X	
D8	X		
D9		X	
D10		X	
D11			X
D12		X	
D13			X
D14			X
D15			X

***Table 1**. Results obtained in some categories of the BSABS (patient 1)*

	DOUBTFUL	YES	NO
C11		X	
C121		X	
C122		X	
C13		X	
C141		X	
C142			X
C143			X
C144		X	
C145		X	
C15		X	
C161		X	
C162		X	
C17		X	
C18		X	
C19		X	
C110		X	
C111		X	
C112		X	
C113		X	
C114			X
C1151		X	
C1152		X	
C116			X
C117		X	
C211			X
C212			X
C213			X
C221		X	
C222		X	
C231			X
C232			X
C233			X
C234			X
C235		X	
C236		X	
C237			X
C238			X
C239			X
C2310	X		
C2311			X
C2312	X		
C241		X	
C242		X	
C251			X
C252			X
C261			X
C262			X
C263			X
C27			X
C28			X
C29			X
C210		X	
C2111			X
C2112		X	
C31		X	
C32		X	
C33			X
C341		X	
C342		X	
C35	X		
D1		X	
D11		X	
D2		X	
D3		X	
D4			X
D5			X
D6		X	
D7			X
D8		X	
D9			X
D10			X
D11		X	
D12	X		
D13			X
D14			X
D15		X	

***Table 2**. Results obtained in some categories of the BSABS (patient 2)*

	Patient 1		Patient 2	
Category	Direct score	Percentil score	Direct score	Percentil score
Loss of control	6	88.1	2	54.9
Simple perception	5	91.1	0	43.0
Complex perception	4	79.5	3	69.3
Language	8	90.1	5	65.2
Thought	7	74.4	6	67.2
Memory	6	77.8	3	53.6
Motility	6	89.4	3	68.6
Loss of automatism	5	68.6	2	41.0
Anhedonia and anxiety	9	98.6	1	32.8
Sensorial overstimulation	9	97.6	4	59.0
Total score	65	87.7	26	47.1
Complementary items	2	34.1	3	53.9

***Table 3**. Results obtained in the FBF*

vulnerability groups: A percentil score of 5 or lower is associated with a very low level of vulnerability, if is comprised between 6-25 to a low level, if 26-74 to a middle level, if 75-94 to a high level and if of 95 or higher to a very high vulnerability group. In patient 1, total score and most subscales -loss of control, simple perception, complex perception, thought, language, memory and motricity- are presumably associated with a high level of vulnerability. As for patient 2, total score and all subscales point to a middle level of vulnerability.

Results corresponding to the ARG may be submitted to the following analysis:

1. Histogram of interval frequencies between blows: The range of values the signal may take (0-300 hundreths of second) is divided into intervals of the same size. The number of points belonging to each interval is then assessed. A bar diagram is thus obtained. A time interval small enough such as 20 hundreths of second was here considered. Values bigger than 300 are grouped in the last bar. The variable "rest" represents the number of points fulfilling this characteristic. When no blows are generated in one or more intervals, a gap or "hole" appears in the figure, representing association between blows.

   A histogram containing a few number of intervals is shown in fig. 1 (patient 1). The presence of a little number of columns suggests that the series is very rhythmic and regular. Fig. 2 shows a significantly higher number of intervals, although gaps corresponding to several intervals also appear (patient 2). This means that the series is more arrhythmic and irregular than the previous one. In fig. 3 (31-years female control), a fewer number of intervals are similarly rep-

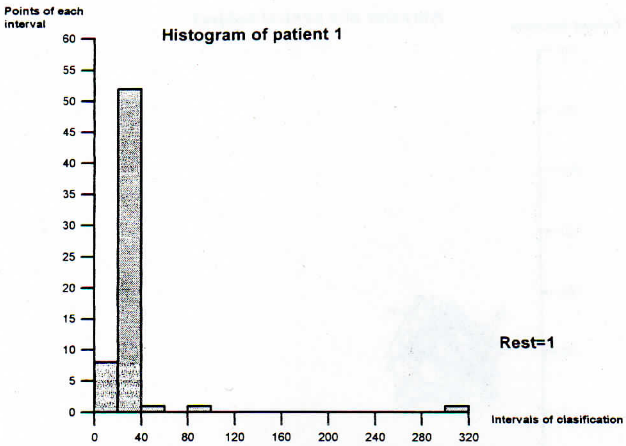

Fig. 1. *Histogram of patient 1*

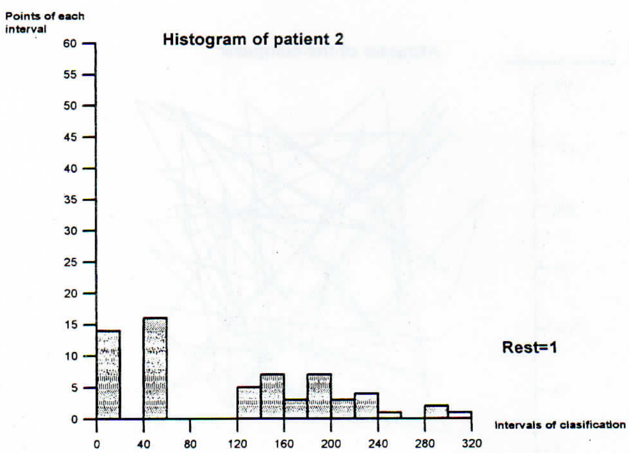

Fig. 2. *Histogram of patient 2*

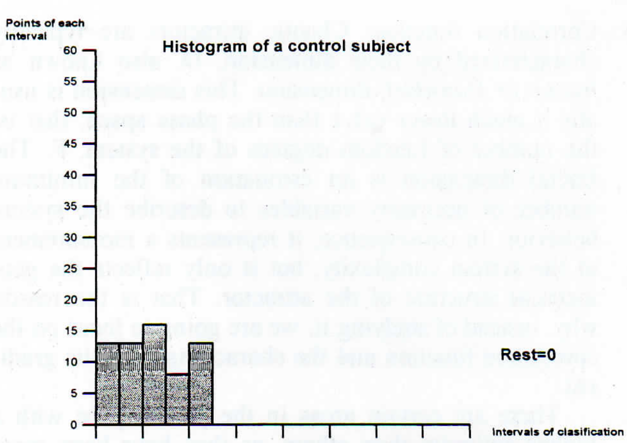

Fig. 3. *Histogram of a control subject*

resented, although no gaps appear between intervals. The figure hints to a higher complexity level when compared to fig. 1. When the computer itself is asked to create the most random series, all intervals are represented and no holes are observed (fig. 4).

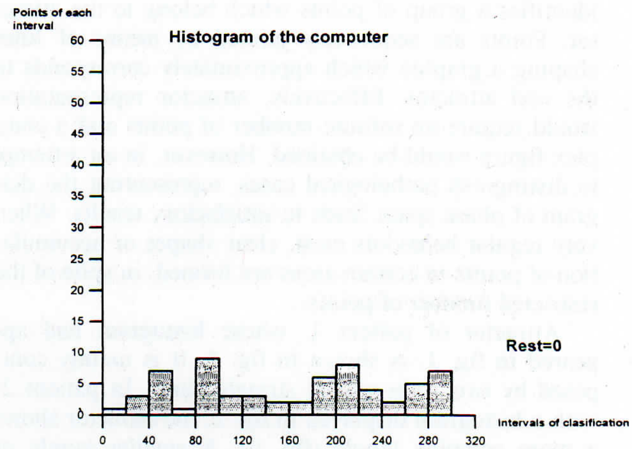

Fig. 4. *Histogram of the computer*

2. Chaotic dynamic attractor: An analysis procedure of the nonlinear complex systems dynamics is representing in the *phase space*. It is defined as a mathematical space of orthogonal coordinates which display every necessary variable to specify the instantaneous system state [3]. It is a hypothetical system which is governed by n variables. Phase space is n-dimensional. Every system state corresponds to a point in the phase space whose n coordinates are variable values for a specific state. For instance, a particle state which is moving along a line is specified by its position and velocity, accordingly its phase space is a plane. If the particle would move in three dimensions, it would have a phase space of dimension 6: the first 3 coordinates would be necessary to know its position and the other 3 for its velocity. By means of this technique values of independent variables changing along time may be tracked.

It is impossible to identify or measure easily the amount of independent variables in many complex systems, as the brain. In these systems, phase space may be represented through the technique of *delay maps*. In the simplest delay map, every point of the graphic corresponds to the value of certain variable in a given moment. This is expressed in relation to the value this very variable takes after a fixed delay period [6]. Studies carried out at the beginning of the 90' showed that the delay map may be built lacking of previous knowledge either about the nature of the variables or the functional shape of differential equations which are able to describe the system. The temporal measurement of a system parameter is sufficient to characterize its dynamics [5]. This is the basis which supports our study.

After essaying several strategies, we have chosen a delay value of 30. Only the points whose coordinates did not exceed the value of 300 have been represented. For higher values, solely a part of certain straight lines is displayed. These lines joint values with their previous and later points, belonging to the square plane defined by the coordinates (0,0) and (300, 300).

If the system is observed during a time period, the sequence of points in the phase space follows a trajectory. This trajectory covers a subspace of the phase space which is called the *system attractor*. The program identifies a group of points which belong to the attractor. Points are sequencely jointed by means of lines shaping a graphic which approximately corresponds to the real attractor. Effectively, attractor representation would require an infinite number of points and a complex figure would be obtained. However, in an atttempt to distinguish pathological cases, representing the diagram of phase space leads to satisfactory results: When very regular behaviors exist, clear shapes or accumulation of points in certain areas are formed, in spite of the restricted number of points.

Attractor of patient 1, whose histogram had appeared in fig. 1, is shown in fig. 5. It is mainly composed by two right-angled straight lines. In patient 2, with a histogram displayed in fig. 2, the attractor shows a more complex tangle (fig. 6). A smaller tangle of points corresponds to the control subject (fig. 7). Her histogram had already been shown in fig. 3. Lastly, attractor of the computer shows a big tangle of points (fig. 8).

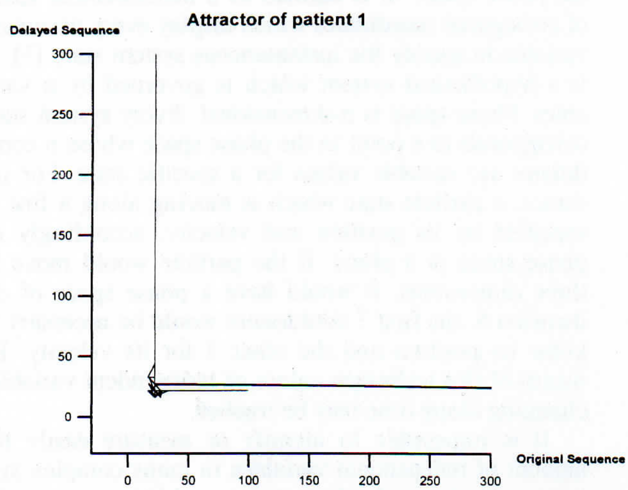

Fig. 5. Attractor of patient 1

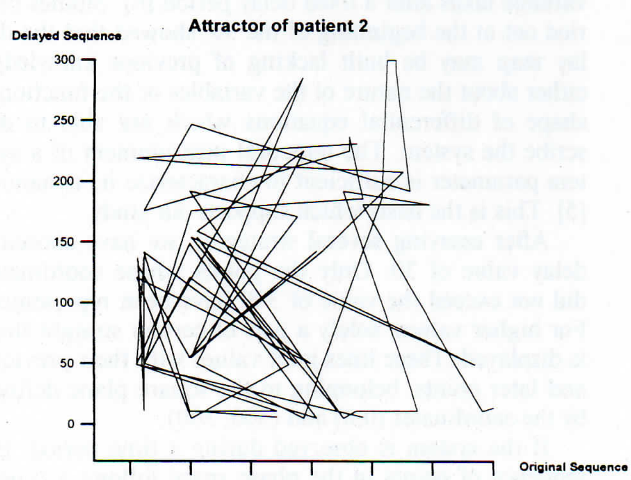

Fig. 6. Attractor of patient 2

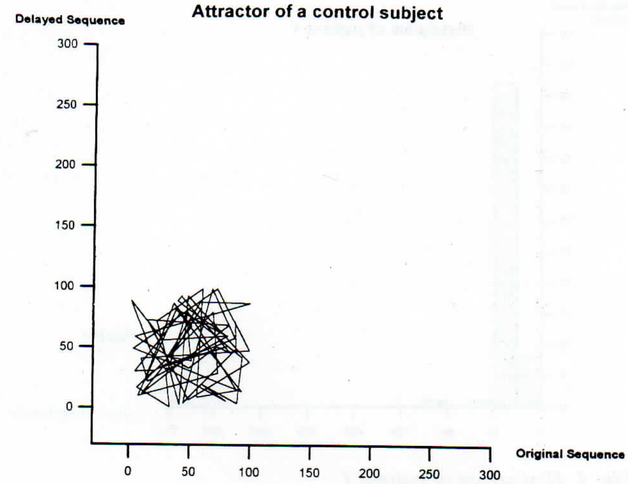

Fig. 7. Attractor of a control subject

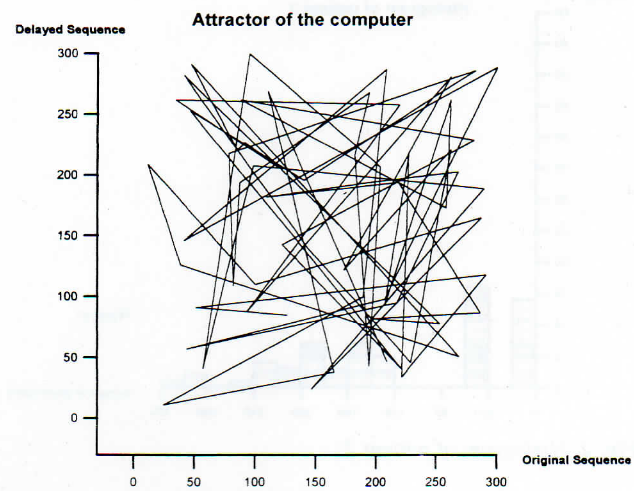

Fig. 8. Attractor of the computer

3. Correlation function: Chaotic attractors are typically characterized by their dimension, D, also known as *fractal or Hausdorff* dimension. This dimension is usually a much lower valve than the phase space, that is, the number of freedom degrees of the system, F. The fractal dimension is an estimation of the minimum number of necessary variables to describe the system behavior. In consequence, it represents a measurement of the system complexity, but it only reflects the geometrical structure of the attractor. That is the reason why, instead of studying it, we are going to focus on the correlation function and the characteristics of its gradient.

There are certain areas in the phase space with a higher antiquity than others, as they have been more frequently visited. While the attractor dimension is unaware of this fact, given that it only reflects the geometrical structure of the attractor, the correlation function is sensitive to it. Obtained graphics show this fact: the more uniform is the distribution of points in the phase space, the closer is the function minimum to the theoretical one (-4.134 in this case), and the more linear is the rising zone of the graphic. Nevertheless, when points tend to be accumulated in certain areas, the graphic is not wholly linear: some steps or regions with a constant value appear.

Therefore, correlation function expresses numerically the coherence level of the system, or in other words, the chaoticity level of the performed series. According to our hypothesis, the fewer gradient, i.e. the more vertical line, the fewer coherence, and therefore the more normality. On the contrary, the fewer gradient or more horizontal line, the bigger coherence and consequently the more pathologic. As an example, see fig. 9-12.

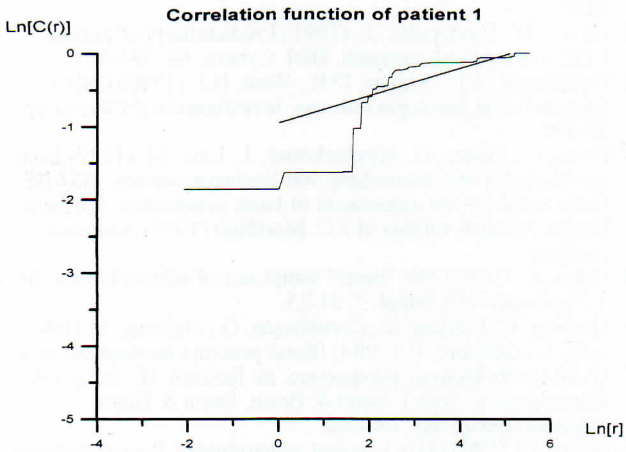

Fig. 9. Correlation function of patient 1

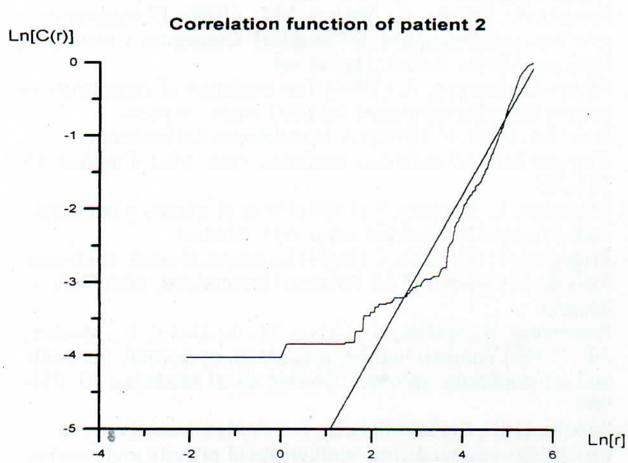

Fig. 10. Correlation function of patient 2

Discussion

As already mentioned, the main objective of this paper is to present a new cognitive technique which is applied by means of a personal computer and which may be useful for the assessment of the schizophrenic patients'cognitive potential. Only preliminary results in the test are here presented. They correspond to two young male patients diagnosed of paranoid schizophrenia, course episodic with interepisode residual symptoms according to DSM-IV criteria. In addition, both of them were identified as suffering from post-psychotic irreversible pure defect [8, 10]. Patient 1, with 23 affirmative answers to symptoms of scale C of

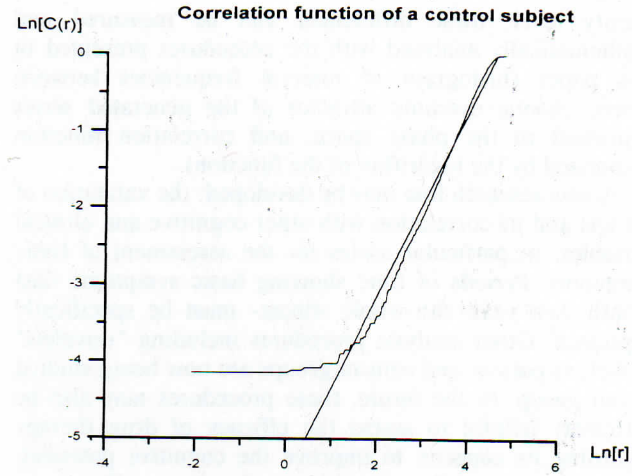

Fig. 11. Correlation function of a control subject

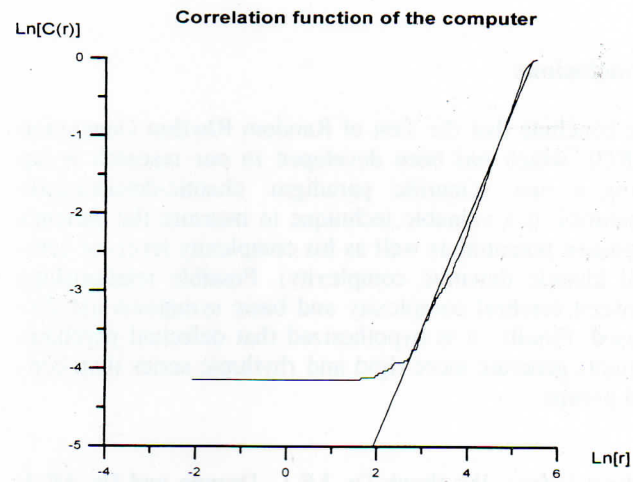

Fig. 12. Correlation function of the computer

the BSABS (cognitive symptoms) and a total score of 65 in the FBF (percentil of 87,7 in relation to a sample of Spanish patients) performed worse in the ARG than patient 2, who answered affirmatively to 32 symptoms of the abovementioned scale C, and to 26 items of the FBF (percentil of 47,1 in relation to the same sample). Nevertheless, although both psychopathological explorations aim at collecting basic symptoms, they usually study different periods of time: last month in the FBF and the whole illness since first experiencing basic symptoms in the BSABS. However, other time intervals can also be examined with the BSABS, according to its authors [7].

These results might suggest that, in chronic schizophrenic patients, a good performance in the ARG would be associated with a low level of present basic symptoms. In the same way, patients who perform poorly in the ARG might simultaneously suffer from more basic symptoms as detected with the FBF. In this sense, the potential relationship between performance in the ARG and basic symptoms the patient has experienced since the onset of the illness remain still uncertain.

Hypothetically, defectual psychotic patients, or at least a subgroup of them, might generate more rigid and rhythmic series than control groups. In order to determine their complexity level, these differences can be measured and mathematically analysed with the procedures presented in this paper (histogram of interval frequencies between blows, chaotic dynamic attractor of the generated series expressed in the phase space, and correlation function (expressed by the logarithm of the function).

A new research line may be developed: the validation of the test and its correlation with other cognitive and clinical variables, in particular scales for the assessment of basic symptoms. Periods of time showing basic symptoms -last month, last year, the whole illness- must be specifically expressed. Other analysis procedures including "wavelets" as well as patient and control groups are now being studied in our group. In the future, these procedures may also be extremely helpful to assess the efficacy of drug therapy regarding its capacity to improve the cognitive potential. We are persuaded that cognitive explorations will accompany psychopathological ones as usual choice methods in the ordinary clinical practice.

Conclusions

We conclude that the Test of Random Rhythm Generation (ARG), which has been developed in our research group using a new scientific paradigm: chaotic-deterministic dynamics, is a valuable technique to measure the patient's cognitive potential as well as his complexity level (or cerebral chaotic dynamic complexity). Possible relationships between cerebral complexity and basic symptoms are discussed. Finally, it is hypothesized that defectual psychotic patients generate more rigid and rhythmic series than control groups.

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