DISSOCIATIVE STATES AND CHAOTIC PATTERNS OF ELECTRODERMAL ACTIVITY DURING ASSOCIATIVE EXPERIMENT

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Abstract

A dynamic concept of schizophrenia linked to the theory of dissociated complexes was experimentally demonstrated by Jung in "The Psychology of the Dementia Praecox". According to him, during schizophrenia the psyche is split-off into a plurality of autonomous complexes and the whole personality is pathologically disintegrated. This pathological disintegration is frequently observed in schizophrenic associations that display "chaotic randomness". The "chaotic randomness" does not mean a true randomness because schizophrenic associations are not without underlying order and causality. An important aspect of schizophrenic dissociation is an extreme subjective sensitivity. These two signs of schizophrenic associations are analogical to known characteristics of chaotic nonlinear dynamical systems. The hypothesis tested in the present study is that neural chaos, calculated from electrodermal activity (EDA), during rest and word-association process is more prominent in schizophrenic patients compared to healthy controls. To test the hypothesis we have measured EDA during the experiment performed in 25 schizophrenic patients and 21 healthy control subjects. Results of non-linear and statistical analysis indicate that the neural chaos characterized by positive largest Lyapunov exponents during rest and the word-association process is significantly higher in the schizophrenic patients. These data suggest that pseudo-randomness of schizophrenic associations and increased sensitivity related to dissociative states might be linked to the chaotic neural dynamics.

Key words: Associations; Chaos; Complex; Dissociation; Schizophrenia

INTRODUCTION

In 1911 Eugen Bleuler in his work *Dementia praecox* or the group of the schizophrenias, introduced the new term to describe this serious illness that replaced Kraepelin's term *dementia praecox*. In his *Text-book of psychiatry* he wrote (Bleuler, 1924): "It is not alone in hysteria that one finds an arrangement of different personalities one succeeding the other. Through similar mechanism schizophrenia produces different personalities existing side by side." (p. 138). The process of splitting in schizophrenia is according to Bleuler (Bleuler, 1924; Rosenbaum, 1980; Bottero, 2001; Scharfetter, 1998) the same as splitting of psychic connections in hysteria or in an extreme version the emergence of alter personalities and typical amnesia. These important Bleuler's ideas with respect to the notion of schizophrenia are historically related to the concept of dissociation devel-

oped by Pierre Janet (Janet, 1890; Ellenberger, 1970; van der Hart & Friedman, 1989; Bob, 2003). Etiology of schizophrenia is thus traditionally explained by Bleuler along the lines of Pierre Janet as being a consequence of dissociative reaction, analogous to somnambulism, fugue states, hypnosis or psychogenic amnesia. Dissociative reaction is most often caused as a consequence of abuse or traumatic experiences leading to a loss of the inhibitory control of certain mental contents with the production of split fragments of the psyche due to abnormal intensive negative affect. Pierre Janet, in his work about psychological automatisms (Janet, 1890; Ellenberger, 1970; van der Hart & Friedman, 1989), defines dissociation as being a defect of the associated system that creates the secondary consciousness, which he called the subconscious fixed idea. Similarly, Sigmund Freud and Joseph Breuer considered double con-

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sciousness in "Studies in hysteria" (Breuer & Freud, 1895). Carl Gustav Jung called these entities psychic complexes. Jung identified these contents in his experiments in Burghölzli and described them in his studies of word associations (Jung, 1968, 1973). When a defect occurs in free associations it is caused by a complex (Jung, 1968, 1972, 1973). A complex always has its own autonomy and behaves as a split part of the psyche. When a complex is evoked into the consciousness, its physiological or pathological influence depends on a degree of its autonomy or, contrary to that, compatibility with other complexes respective to the ego-complex. In the case of pathological influence the complex leads to a lowered mental level, (*abaissement du niveau mental*) (Janet, 1890; Ellenberger, 1970; van der Hart & Friedman, 1989).

The fundamental causes of the etiology of pathological dissociated complexes, as Janet suggested, are mainly traumatic events, which produce traumatic memories. Complexes thus generate alternate fields of the psyche, and it is possible, by means of these complexes, to explain also extreme cases which occur in multiple personality disorder (MPD) (Bob, 2004). In the *The Psychology of the Dementia Praecox*, Jung experimentally demonstrated a dynamic concept of schizophrenia based on the theory of dissociated complexes (Jung, 1909; Ellenberger, 1970). He applied the associative experiment to schizophrenic subjects and compared these results to experiments performed with normal persons. These experiments led him to define a condition of inner distraction determined by complex, which corresponds to Weygandt's term 'apperceptive deterioration' and is closely related to the concept of "*abaissement du niveau mental*" proposed by Janet as the cause of dissociation (Jung, 1909; Ellenberger, 1970). Jung's experimental findings with neurotic and psychotic patients, and also with normal persons have documented material supporting Bleuler's clinical hypothesis regarding the common mechanisms underlying the formation of symptoms in hysteria and the symptoms in dementia praecox (Jung, 1909; Ellenberger, 1970). According to Jung, during schizophrenia the psyche is split-off into a plurality of autonomous complexes and the whole personality is pathologically disintegrated. This pathological disintegration is obvious from schizophrenic associations and in this context Jung wrote that schizophrenic associations: "... are unsystematic, abrupt, grotesque, absurd, and correspondingly difficult if not impossible to understand. Not only are the products of schizophrenic compensation archaic, they are further distorted by their chaotic randomness." (Jung, 1972). This chaotic randomness does not mean stochasticity as a true randomness because it is known that schizophrenic associations are not without underlying order and causality. Deeper understanding of schizophrenic associations often may recover key traumatic experiences that

played a significant role in the later progress of dissociation (Jung, 1968). Another important aspect of dissociation is an extreme sensitivity which is caused by a system of ego-defenses and during association emerges as 'a condition of inner distraction'. Those two characters of schizophrenic associations strongly correspond to known mathematical characteristics of chaotic nonlinear dynamical systems. The first characteristic of these systems is the pseudorandom behavior which is neither deterministic causality nor stochastic randomness but causally determined process with seemingly random behavior. Chaotic systems display the sensitivity which in extreme case corresponds to metaphor whether or not a butterfly flaps its wing in one part of the world may cause a tornado in some other part of the world, the so-called exponential divergence, which characterizes sensitivity of dynamic system with respect to very small changes (Isaacs, 2003). Mathematically this degree of sensitivity characterizes the so-called Lyapunov exponent. For positive Lyapunov exponent (number larger than zero) the state of the system is chaotic and degree of chaos elevates with increasing of Lyapunov exponent. For negative Lyapunov exponent the state is stable and deterministic. For zero Lyapunov exponent the state may tend to periodic repetitive behavior (Kantz & Schreiber, 1997).

If we consider the mind and brain as mutually connected subsystems it is possible to suggest the hypothesis that dissociated complex related to inner distraction during associative experiment is related to increased chaoticity in the brain measured by psychophysiological measures such as electrodermal activity (EDA).

Research of the relationship between EDA and dissociation has historical tradition beginning at the break of 19th and 20th century. In 1908 M. Prince and F. Peterson reported EDA measurement (the so-called galvanic skin response- GSR) in a patient with MPD and found distinct emotional reactions on personally meaningful stimuli indicating amnesic barrier among different personalities (Prince & Peterson, 1908). At the same time Jung published his famous work "On psychophysical reactions of the associative experiments" that has documented direct relationship between EDA response and dissociated complexes of individual behavior patterns evidenced in word associations (Jung, 1907, 1910, 1968; Naifeh, 2001). Recent evidence indicates that EDA is governed mainly by limbic modulation influences and correlates with amygdala activity (although other structures such as ventromedial and dorsolateral prefrontal cortices, anterior cingulate gyrus, parietal lobe, insula and hippocampus are also involved) (Mangina & Beuzeron-Mangina, 1996; Critchley, 2002; Phelps et al., 2001). For example, according to intracranial study by Mangina and Beuzeron-Mangina (1996) increased activity in the limbic structures caused by electrical stimulation relates to increased ipsilateral

EDA. Typical for EDA is that it reflects activity within the sympathetic axis of the autonomic nervous system. Sympathetic activity is closely linked to emotion, and EDA is widely used as sensitive index of emotion-related sympathetic activity (Dawson, Shell, & Filion, 2000; Critchley, 2002). Dynamic changes of EDA thus likely may serve as a characteristic that can indicate emotional chaotic process during associative experiment and show whether association disturbances in schizophrenic patients during associative experiment are related to significantly higher chaoticity measured by Lyapunov exponents in EDA than it is in normal control group.

METHOD

Participants

The participants consisted of 25 adult schizophrenic outpatients of University Hospital (mean of age 28) and 21 healthy controls from general population (mean of age 22). The 14 males and 11 females from schizophrenia group, and the 9 males and 12 females from the healthy control group took part in the study. Schizophrenic patients had diagnosis of paranoid schizophrenia. All the schizophrenia patients were in partial remission. Their treatment at the time of the recruitment was based on antipsychotic medication. Exclusion criteria were organic illnesses involving the central nervous system, substance, and/or alcohol abuse, mental retardation and significant extra-pyramidal symptomatology. Two of the authors of this article independently reexamined the patient's diagnoses according to DSM IV criteria. All the participants were strongly right handed according to Waterloo Handedness Questionnaire (Elias, Bryden, & Bulman-Fleming, 1998).

Design

After obtaining informed consent from the participant, the EDA was recorded bilaterally using two channels SAM unit and Psylab software (Contact Precision Instruments) connected to personal computer. Measurement was performed in a quiet room, with room temperature of about 21°C (69.8 F). The participant was instructed to sit down into comfortable chair. Then two pairs of Ag/AgCl electrodes (8 mm diameter active area) filled with electro-conductive-paste were attached to medial phalanges of the index and middle finger of each hand. After five minutes long resting state with closed eyes experimental EDA recording during rest and association experiment began and takes time about 5 minutes (2 minutes before and about 3 minutes during association experiment).

Word-association test

The test is a research and diagnostic technique at first introduced by psychologist and scientist Francis Galton and later in 1904 reinvented by C.G. Jung (Jung, 1907;

Colman, 2003). In the common technique popularized by Jung a list of stimulus words is read out and the subject responds to each stimulus word as quickly as possible with the first response word that comes to mind. The list of stimulus words contains a wide range of topics and includes a number of critical words that are likely to have particular psychological significance that may recall defense mechanism related to dissociated complex (Jung, 1907, 1910, 1968; Kondas, 1989). During experiment 30 selected stimulus words (with critical words in *italic*) in the following order were presented:

Brook, lion, book, dark, love, child, table, head, sex, boy, illness, hand, hill, cry, needle, family, death, cheese, moon, fear, window, street, punishment, salt, man, anger, soldier, doctor.

Data Analysis

The analysis of the EDA time series in resting state and during the associative experiment was performed using the software package Dataplore valued as one of the most and well known software for the time series analysis. 200 seconds EDA records (100 s before and 100 s during word-association test) were divided on 4 second intervals (which include 4000 datapoints) and then non-linear analysis was performed. In the data analysis by common technique mutual information, False Nearest Neighbours, embedding dimension and Lyapunov exponents were calculated (Kantz & Schreiber, 1997). False Nearest Neighbours technique utilizes geometric principles for the finding of embedding dimension which determines reconstruction of underlying chaotic dynamics by means of Lyapunov exponents (Kantz & Schreiber, 1997).

A difference between degree of chaos measured by positive Lyapunov exponents in resting state and during the associative experiment was assessed in a statistical evaluation that included means, standard deviation and t-test for independent samples.

Results

Results of descriptive statistics for positive Lyapunov exponents, which describe chaotic behavior during resting state and during the associative experiment support the stated hypothesis that increased inner distraction during associative experiment likely relates to increased chaoticity in the brain measured by EDA (Table 1, Figure 1). The data indicate that the state during the associative experiment related to recall of the complexes is significantly more chaotic than the resting state before the experiment in both schizophrenic patients and in the control group. The results also indicate that dynamic changes measured by Lyapunov exponents in EDA discriminate between groups of schizophrenic patients and normal controls, because schizophrenic patients display significantly higher Lyapunov exponents during resting

on both sides (L,R) than the control subjects (t-test between sch.restL and cont.restL is 4.32 for $p=0.00008$; t-test between sch.restR and cont.restR is 3.28 for $p=0.002$). Also association disturbances in schizophrenic patients during associative experiment are related to significantly higher Lyapunov exponents on the left side with respect to the normal control group which indicates defect predominantly in the left hemisphere (predominantly verbal) as characteristic of schizophrenic disorder, while the difference on the right side of both groups during associative experiment is not statistically significant (t-test between sch.asoc.L and cont.asoc.L is 3.19 for $p=0.002$; t-test between sch. asoc.R and cont. asoc.R is 0.78 for $p=0.43$).

Table 1. Descriptive statistics of positive Lyapunov exponents that describe chaotic changes in EDA in resting state and during the associative experiment.

Subjects	Lyapunov exponents; resting state		Lyapunov exponent associative experim	
	Mean	SD	Mean	SD
Schiz. L	0.041	0.019	0.062	0.043
Schiz. R	0.334	0.014	0.044	0.023
Cont. L	0.021	0.008	0.030	0.016
Cont. R	0.022	0.008	0.037	0.034

Note. L-left; R-right; Schiz.- schizophrenic patient; Cont.- normal control subjects; Embedding dimension is 1 for all measured intervals; Values with negative Lyapunov exponent were excluded; df- degree of freedom for the t-tests in schizophrenic patients is 48 and in the control group is 40.

DISCUSSION

Results of this study indicate significant differences of Lyapunov exponents between resting state and the state during the word-association experiment. This might be interpreted that the state during the word-association experiment is significantly more chaotic than the resting state. The data thus hypothetically suggest an underlying chaotic process in temporolimbic structures (mainly in the amygdala) which may modulate EDA in both states during rest and associative experiment when released affect related to feeling-toned complex increases. These data suggest that pseudo-randomness of schizophrenic associations and increased sensitivity during dissociative states might be connected to chaotic states on psychophysiological level.

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REFERENCES

Bleuler, E. (1911/1955). *Dementia praecox or the group of the schizophrenias*. New York: International University Press.

Bleuler, E. (1924). *Textbook of Psychiatry*. Brill, A.A. (trans.). New York: Macmillan Publishing Co. Inc.

Bob, P. (2003). Subliminal processes dissociation and the 'I'. *Journal of Analytical Psychology*, 48, 307-316.

Bob, P. (2004). Dissociative processes, multiple personality and dream functions. *American Journal of Psychotherapy*, 58, 139-149.

Bottero, A. (2001). A history of dissociative schizophrenia. *L' Evolution Psychiatrique*, 66, 43-60.

Breuer, J., & Freud, S. (1895). *Studies in hysteria*. New York: Basic Books.

Colman, A.M. (2003). *A Dictionary of Psychology*. New York: Oxford University Press.

Critchley, H.D. (2002). Electrodermal Responses: What Happens in the Brain. *Neuroscientist* 8, 132-142.

Dawson, M.E., Shell, A.M., & Fillion, D.L. (2000). The electrodermal system. In J.T. Cacioppo, L.G. Tassinary, & G.C. Bernston (Eds.), *Handbook of Psychophysiology*. 2nd ed. Cambridge, MA: Cambridge University Press. 200-23.

Ellenberger, H.F. (1970). *The Discovery of the Unconscious: The History and Evolution of Dynamic Psychiatry*. New York: Basic.

Elias, L.J., Bryden, M.P., & Bulman-Fleming, M.B. (1998). Footedness is better predictor than handedness of emotional lateralization. *Neuropsychologia*, 36, 37-43.

Isaacs, A., Daintith, J., and Martin, E. (2003). *Oxford Dictionary of Science*. New York: Oxford University Press.

Janet, P. (1890). *L'Automatisme Psychologique*. Paris: Felix Alcon.

Jung, C.G. (1907). On psychophysical relations of the associative experiment. *Journal of Abnormal Psychology*, 1, 247-255.

Jung, C.G. (1909). *The Psychology of Dementia Praecox*. New York: Journal of Nervous and Mental Disease Publishing Company; also in CW3.

Jung, C.G. (1910). The association method. *American Journal of Psychology*, 31, 219-269.

Jung, C.G. (1972). *Schizophrenia. Collected Works of C. G. Jung 3*. Princeton: Princeton University Press.

Jung, C. G. (1968). *Analytical Psychology: Its Theory and Practice*. London: Routledge & Kegan Paul.

Jung, C. G. (1973). *Collected Works of C. G. Jung 2*. Princeton: Princeton University Press

Jung, C.G. (1972). A Review of the Complex Theory. The structure and dynamics of the psyche. In *Collected Works of C.G. Jung 8*. Princeton: Princeton University Press.

Kantz, H. & Schreiber, T. (1997). *Nonlinear time series analysis*. Cambridge: Cambridge University Press.

Kondas, O. (1989). *Associative Experiment [Asociační experiment]*. J Bratislava: Psychodiagnostika.

Mangina, C.A., Beuzeron-Mangina, J.H. (1996). Direct electrical stimulation of specific human brain structures and bilateral electrodermal activity. *International Journal of Psychophysiology*, 22, 1-8.

Naifeh, S.C. (2001). Carl Gustav Jung, M.D., 1875-1961. *American Journal of Psychiatry*, 158, 1973.

Phelps, E.A., O'Connor, K.J., Gatenby, J.C., Gore, J.C., Grillon, C., & Davis, M. (2001). Activation of the left amygdala to a cognitive representation of fear. *Nature Neuroscience*, 4, 437-441.

Prince, M. & Peterson, F. (1908). Experiments in psychogalvanic reactions from co-conscious ideas in a case of multiple personality. *Journal of Abnormal Psychology*, 3, 114-131.

- Rosenbaum, M. (1980). The role of the term schizophrenia in the decline of diagnoses of multiple personality. *Archives of General Psychiatry*, 37, 1383-1385.
- Scharfetter, C. (1998). Dissociation and schizophrenia. Schizophrenias- a dissociative nosopoietic construct? *Fortschritte der Neurologie-Psychiatrie*, 66, 520-3.
- van der Hart, O., & Friedman, B. (1989). A reader's guide to Pierre Janet on dissociation: A neglected intellectual heritage. *Dissociation*, 2, 3-16.