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DESCRIPTION OF UNDERLYING DYNAMICS
AND ITS RELATION TO DISSOCIATIVE
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I. INTRODUCTION

Given the need for further articulation of the characteristics of "error prone state" or "hazardous states of awareness", this NASA grant focused on basic ground work for the study of the psychophysiology of these states. In specific, the purpose of this grant was to establish the necessary methodology for addressing 3 broad questions.

Question 1: How should the "error prone state" or "hazardous state of awareness" be conceptualized? Is it similar to a dissociative state, an hypnotic state, absent mindedness, etc.?

Question 2: Are some individuals more prone to enter these states than others?

Question 3: Can the recent research in nonlinear dynamics (i.e., chaos) offer an addition and/or alternative to traditional signal processing methods (e.g., FFTs). Can the chaos procedures be modified to offer additional information useful in identifying brain states?

II. METHODOLOGICAL AND EXPERIMENTAL STUDIES

Question 1: How should the "error prone state" or "hazardous state of awareness" be conceptualized? Is it similar to a dissociative state, an hypnotic state, absent mindedness, etc.?

The Aviation Safety Reporting System (ASRS) database shows that civil transport flight crews often describe error incidents as related to particular states of awareness characterized by lapses of attention, as well as diminished vigilance and alertness. A further analysis of these data suggests that lapses of awareness, although involved in accidents, may occur frequently without actual incident (cf. Pope & Bogart, 1992) suggesting that such states may be a necessary but not sufficient condition for certain types of accidents. The implication for this is that if the hazardous state could be identified and acted upon, it could prevent a transition into an error state. Although the literature has discussed such a hazardous state as "highway hypnosis", "lost in thought", "absorbed", "preoccupied" and other similar terms, we are only beginning to understand how these states are theoretically related. Technically, these states share the conceptual requirement for dissociative experiences which have been measured psychometrically by the *Dissociation Experiences*

Questionnaire (DES) and the *Questionnaire of Experiences of Dissociation* (QED)(Bernstein & Putnman, 1986; Riley, 1988). In studies of accidents and errors, researchers such as James Reason and Donald Broadbent have developed questionnaires for determining lapses of awareness and absent mindedness(Broadbent et al., 1982; Reason, 1982,1990). Although these potentially hazardous states of awareness have been described, there exists little empirical literature to describe the underlying structure of and relationships between these measures.

In the first series of studies over 1200 subjects completed a variety of psychometric measures reflecting internal states and proneness to mental lapses and absent mindedness.

Study 1: Using the two measures developed for the analysis of errors— Broadbent's *Cognitive Failures Questionnaire* (CFQ) and Reason's *Absentmindedness Questionnaire*, (abmind) positive correlations were found between these measures and the two dissociation questionnaires (DES & QED) suggesting at least one similar factor underlying these measures. (NOTE: **=p<.01)

correlation/ N	DES	QED	CFQ	Abmind
DES		.80**	.47**	.56**
QED	904		.63**	.56**
CFQ	540	254		.68**
Abmind	249	249	541	

Study 2: Since dissociative experiences have been viewed as conceptually similar to the hypnotic process as when lapses in awareness while driving are referred to as "highway hypnosis", scores on the two dissociation scales were compared with those of a standard scale of hypnotic susceptibility (*Harvard Scale of Hypnotic Susceptibility*). These data suggest that there is no relationship between prior dissociative experiences and the ability to enter into a standard hypnotic trance. Likewise, scores on the *Absent Mindedness Scale* and the *Cognitive Failures Questionnaire* are not associated with hypnotic susceptibility.

correlation/ N	DES	QED	CFQ	Abmind
Harvard Scale of Hypnotic Susceptibility	.09 N=853	.10 N=662	.02 N=444	.04 N=247

Study 3: Since one aspect of a hazardous state may be absorption into non task-relevant processes, the *Tellegan Absorption Scale* (Tellegen & Atkinson, 1974) was correlated with both the dissociation and error scales. These data suggest that absorption shows a larger relationship with dissociation than with either the error or absent mindedness scales.

	DES	QED	CFQ	Abmind
Absorption N=243	.55**	.59**	.27**	.37**

Question 2: Are some individuals more prone to enter these states than others?

The preceding psychometric studies suggest that there exists a consistency of patterns displayed by individuals who self-report dissociative experiences such that those individuals who score high on measures of dissociation also score high on measures of absent mindedness, errors, and absorption, but not on scales of hypnotizability. For the study of lapses of awareness, it may be advantageous to select subjects who report prior dissociative experiences or score high on the absent mindedness and cognitive failures scales to maximize potential entry into hazardous states of awareness. Before such subjects can be studied within an ecologically valid task, such as a flight simulation procedure, it is important to establish any initial psychophysiological differences that exist in these populations since there exist little data concerning their psychophysiological concomitants.

Study 4: In this study 14 young adults who scored either high or low on the *Dissociation Experiences Scale* (DES) performed a series of six tasks. The tasks were chosen to reflect the type of distractions reported in the ASRS that occurred prior to error incidents. This included tasks which were cognitively demanding and engaging (e.g., mental math); tasks whch reflected recalling personal emotional events (e.g., positive and negative emotionality); and a neurtal color imagery task. The order of the tasks were as follows: (1) imagine a color; (2) solve mental math problem; (3) positive emotional imagery; (4) mental math; (5) negative emotional imagery; (6) image a counting task. Preceding each task, a 30 second baseline was taken. EEG was measured using 8 sites (F_3, F_4, T_3, T_4, P_3, P_4, O_1, O_2) with linked ears as a reference. The sample rate was 100 Hz with a .03-35 Hz bandpass and 2 EOG channels for artifact correction. The EEG data were Fourier analyzed into theta, alpha, and beta frequency bands and log transformed for ANOVAs.

In terms of the initial baseline, we found no significant differences between high and low DES Ss in any of the three EEG bands examined (see Figure 1).

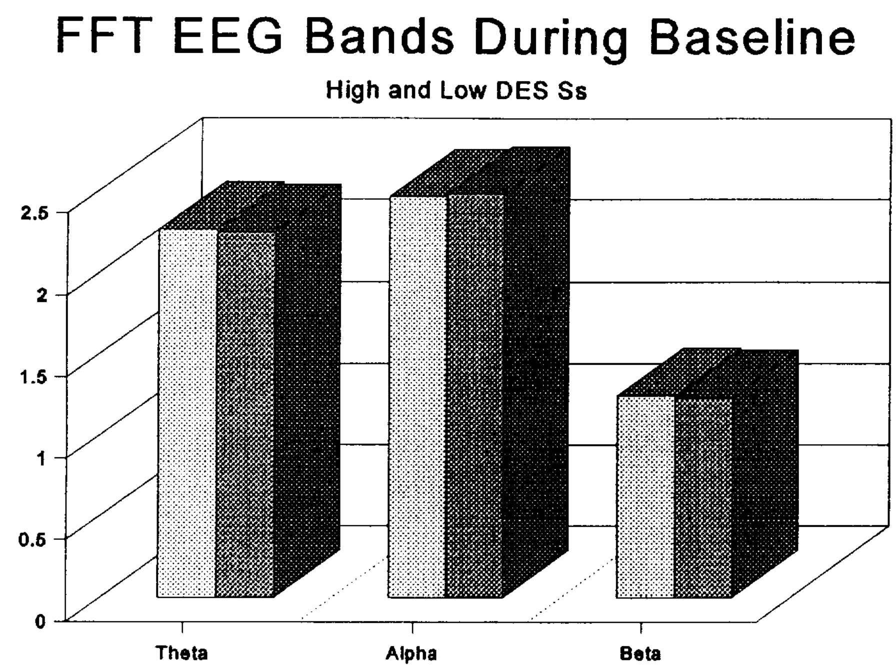

Figure 1: EEG bands during baseline for high and low dissociation Ss.

These results can be contrasted with previous EEG work which examined high and low hypnotic susceptible Ss (Graffin, Ray, & Lundy, 1994). In this study, EEG baseline differences were found in the theta bands for Ss differing in hypnotic susceptibility. Thus, using both psychometric and psychophysiological procedures, it can be concluded that psychometric measures of dissociation, absent mindedness, and cognitive errors represent a similar underlying process and that this process is orthogonal to that of hypnotic susceptibility.

In terms of emotionally valenced imagery (positive vs negative), there was a significant interaction between DES group, emotionality, and site in the theta band ($F(3,36) = 2.95$; $P < .05$) and the beta band ($F(3,36) = 7.03$; $P < .0008$) (see Figures 2 & 3).

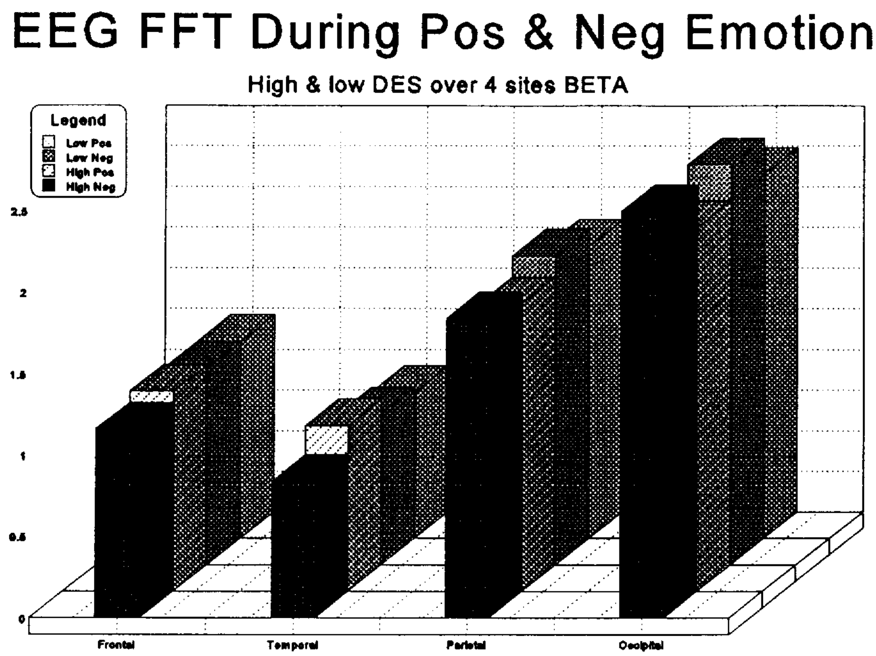

Figure 2: EEG beta during positive and negative emotion for four sites by dissociation group.

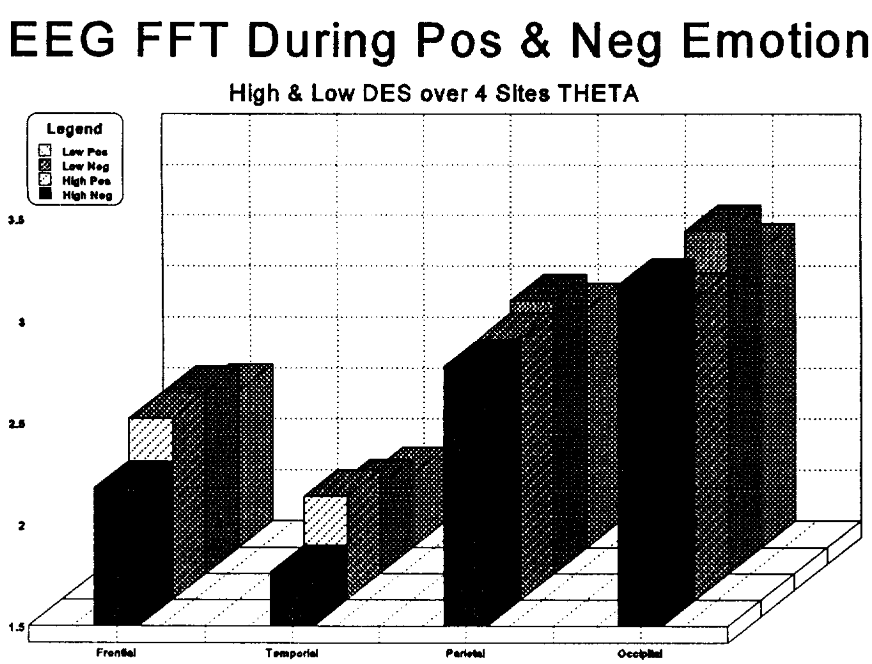

Figure 3: EEG theta during positive and negative emotion for four sites by dissociation group

It can be observed from both Figures 2 & 3 that the low dissociative subjects show more theta and beta power during the negative emotional tasks and that the high dissociative Ss show an opposite pattern for the frontal area (i.e., frontal and temporal) and a similar pattern for the posterior areas (parietal and occipital).

In terms of mental math, there were no significant differences nor interactions involving the dissociation groups. There were, however, a significant site (frontal, temporal, parietal, occipital) by hemisphere interaction for the theta ($F(3,36)=332.36$; $p<.0001$), alpha ($F(3,36)=110.31$; $p<.0001$), and beta ($F(3,36)=188.72$; $p<.0001$) bands. Inspection of the data shows greater EEG power in the right parietal as compared to the left parietal areas with the other sites showing little or no hemispheric differentiation.

Overall, these data suggest that high and low dissociative individuals arrive at the experiment (i.e., baseline) in similar electrocortical states and perform cognitive tasks (e.g., mental math) in a similar manner. It is in the processing of internal emotional states that differences begin to emerge. The next step in a future grant is to address these groups using ecologically valid tasks. In preparation for this we have modified the MAT (see Moraga & Ray, 1993) to better study transitional states in awareness with the goal of identifying marker variables for these lapses of attention and entry into hazardous states. Future studies will emphasize high dissociative individuals since they have a history of experiencing lapses of awareness.

Question 3: Can the recent research in nonlinear dynamics (i.e., chaos) offer an addition and/or alternative to traditional signal processing methods (e.g., FFTs)? Can the chaos procedures be modified to offer additional information useful in identifying brain states?

As an initial step, applications of nonlinear dynamics to the physiological literature was reviewed (Elbert, Ray, et al. 1994). This review suggests that current nonlinear dynamical techniques (e.g., dimensional analysis) can be successfully applied to electrocortical activity. Using the data set developed in study 4, we performed chaos analyses using the Farmer algorithm to determine the average pointwise dimension. As described previously, the data were subjected to a principal components analysis (PCA) prior to determining dimensionality (Lutzenberger et al., 1992).

As with the FFT data, there were no initial baseline differences in dimensionality between the two dissociation groups. When examining all six baselines (a baseline precedes and follows each task), there was an interaction involving dissociation group, baselines, and site ($F(15,75)= 2.17$, $p<.015$). Inspection of these data shows that the high dissociation Ss evidenced a reduction in dimensionality following the negative emotionality trial (baseline 6) in the temporal area whereas the low dissociation Ss did not. These data are presented in Figure 4 (High Dissociation) & 5 (Low Dissociation).

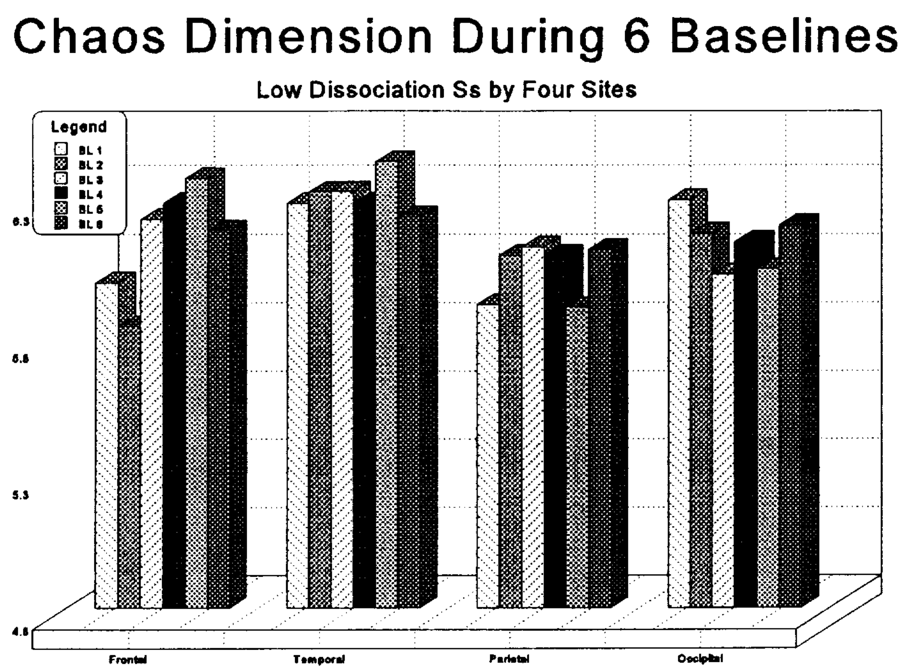

Figure 4: Dimensionality of low dissociation Ss during 6 baselines by four sites.

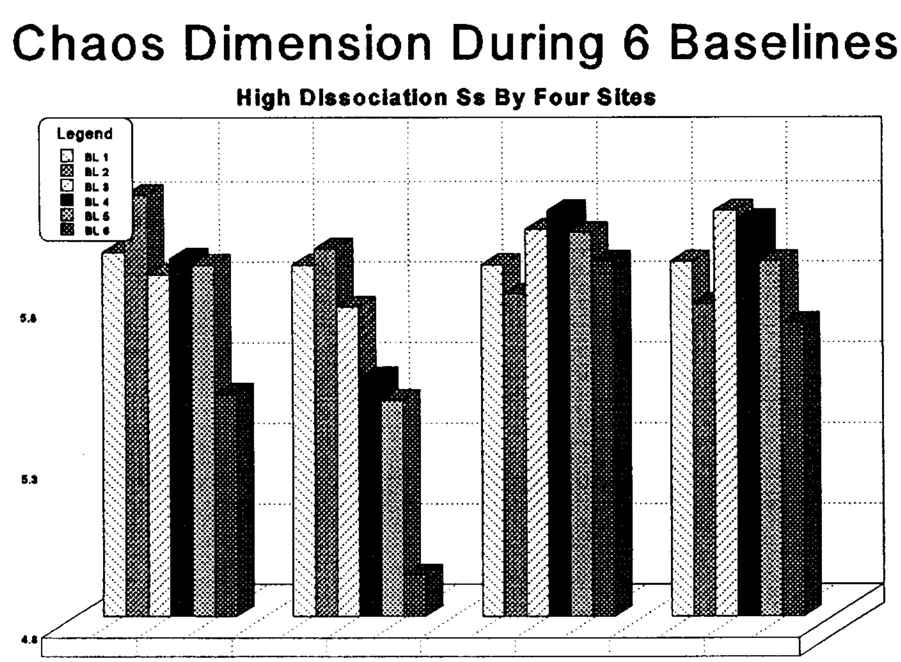

Figure 5: Dimensionality of high dissociation Ss during 6 baselines by four sites.

There were also task differences in terms of dimensionality at specific sites although this was not mediated by dimensionality group. In general, the dimensionality found from the emotional imagery tasks were consistent across the cortex whereas the dimensionality involved in the mental math tasks was lower in the more frontal (frontal & temporal) areas of the cortex. These data are presented in Figure 6 & 7.

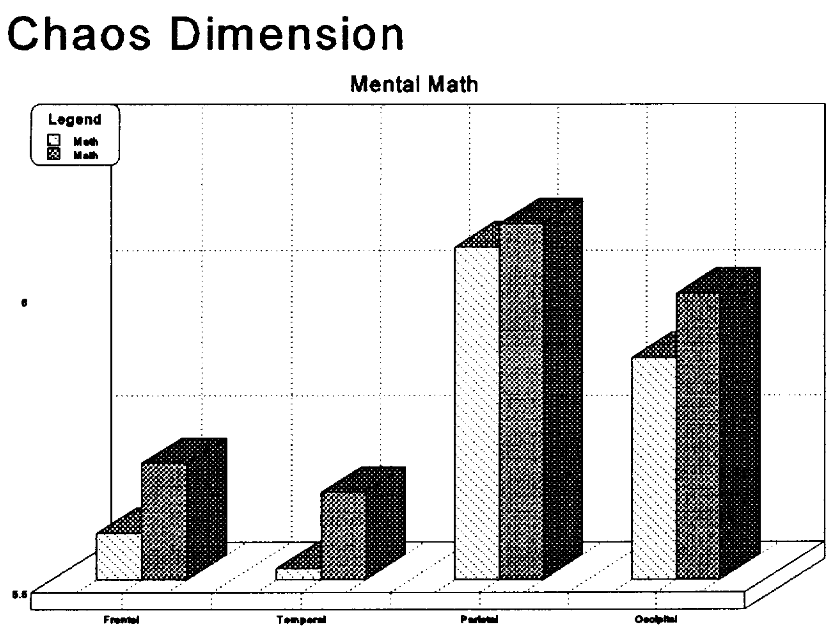

Figure 6: Chaos Dimension for 2 mental math problems showing lower dimensions in the frontal compared to the posterior areas.

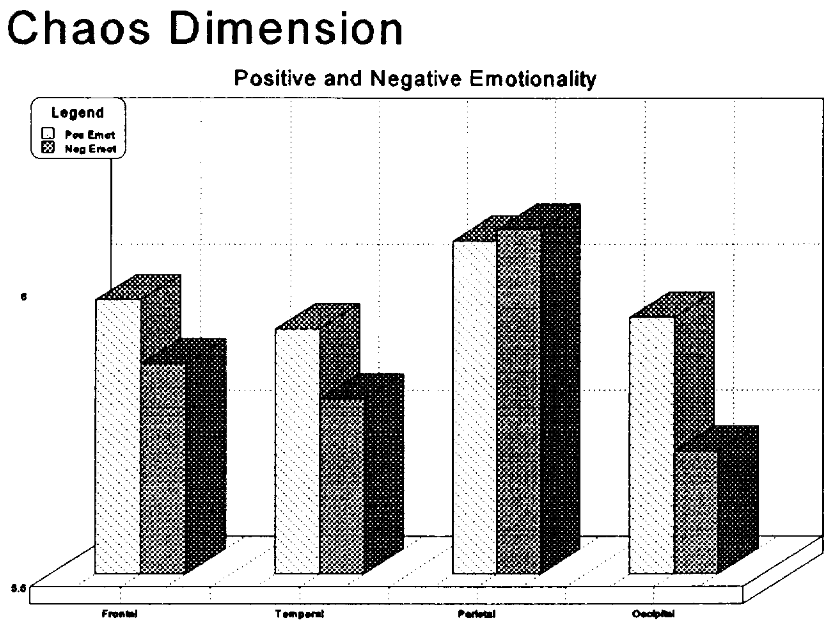

Figure 7: Chaos Dimension for positive and negative emotional tasks.

At this point, the necessary computational procedures have been developed and utilized for processing the data described. These results appear robust since they have been replicated with a European population. Overall, this research suggests that dimensionality measures reflect information not contained in traditional EEG Fourier analysis. These result as described give us the necessary baseline measures to move to more ecologically valid tasks. One goal of our work has been the application of analytical procedures based on nonlinear dynamical system theory to electrocortical measurements. The goal of this work is the identification of states especially as related to the process of error production and lapses of awareness as might be experienced during aviation.

III. PUBLICATION CONNECTED WITH THIS GRANT.

During the duration of this grant the following were published acknowledging NASA's support.

Ray, W.J. (1993) EEG and chaos: Exploations in using dimensional estimation to estimate psychological state. In T. Kikuchi (Ed.) *Biobehavioral self-regulation in the East and the West.* Springer-Verlag, Tokyo.

Ray, W.J., Moraga, R., Elbert, T., Lutzenberger, W., & Birbaumer, N. (1993) Non-linear dynamical analysis of the EEG in task and individual differences. *Psychophysiology, 30,* S53 (abstract).

Ray, W.J., & Faith, M. (1993) EEG processing of emotional material in high and low dissociative individuals. *Psychophysiology, 30,* S52 (abstract).

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