

COMORBIDITY IN PSYCHIATRIC AND CHRONIC PHYSICAL DISEASE: AUTOCOGNITIVE DEVELOPMENTAL DISORDERS OF STRUCTURED PSYCHOSOCIAL STRESS

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ABSTRACT

Applying a 'necessary condition' communication theory formalism roughly similar to that of Dretske, but focused entirely on the statistical properties of long sequences of signals emitted by the interacting cognitive modules of human biology, we explore the regularities apparent in comorbid psychiatric and chronic physical disorders using an extension of recent perspectives on autoimmune disease. We find that structured psychosocial stress can literally write a distorted image of itself onto child development, resulting in a life course trajectory to characteristic forms of comorbid mind/body dysfunction affecting both dominant and subordinate populations within a pathogenic social hierarchy.

Keywords: chronic disease, cognition, comorbidity, developmental disorder, hierarchy, information theory, mental disorder, psychosocial stress, punctuated equilibrium.

1. INTRODUCTION

Certain mental disorders, for example depression and substance abuse, and many physical conditions like lupus, coronary heart disease, hypertension, breast and prostate cancers, diabetes, obesity, and asthma, show marked regularities at the community level of organization according to the social constructs of 'race', 'ethnicity' and 'socioeconomic status'. Indeed, a virtual research industry has emerged in the United States to address the 'mystery' of such 'health disparities'. Population-level structure in disease permits profound insight into etiology because, to the extent these are 'environmental' disorders, the principal environment of humans is other humans, moderated by a uniquely characteristic embedding cultural context (e.g. Durham, 1991). Thus culturally-sculpted 'social exposures' are likely to be important at the individual and critical at the population levels of organization in the expression of certain mental disorders and a plethora of chronic diseases.



Further, mental disorders are often comorbidly expressed, both among themselves and with certain kinds of chronic physical disorder: Picture the obese, diabetic, depressed, anxious patient suffering from high blood pressure, asthma, coronary heart disease, and so on. Such comorbidity is the rule rather than the exception for the seriously ill and is the central focus of this work.

As Cohen (2000) describes for autoimmune disease, however, the appearance of comorbid and anticomorbid conditions is, given the possibilities, rather surprisingly constrained to a relatively few often-recurring patterns. We will find this to be a central point.

Here we study how a long list of 'cognitive submodules' may become synergistically linked with embedding, culturally structured, psychosocial stress to produce comorbid patterns of illness associated with mental disorder and chronic disease. We will further suggest that many such disorders either have their roots in utero, as a stressed mother communicates environmental signals across the placenta, and programs her developing child's physiology, or else are initiated during early childhood. This pattern may affect underlying susceptibility to chronic infections or parasitic infestation as well as more 'systemic' disorders (e.g. Wallace and Wallace, 2002).

We are, then, particularly interested in the effects of 'stress' on the interaction between mind and body over the life course. 'Stress', we aver, is most frequently a socially constructed cultural artifact, a very highly organized 'language' having both a grammar and a syntax. That is, certain stressors are 'meaningful' in a particular developmental context, and others are not, having little or no long-term physiological effect. We first argue that rational thought, emotion, immune function, related physiological processes like the hypothalamic-pituitary-adrenal (HPA) axis, blood pressure regulation, and sociocultural network function are, in fact, formally, if often weakly, cognitive systems. Each is associated with a 'dual information source' which may also be expressed as a kind of language. It is the punctuated interpenetration of these 'languages' which we will find critical to an understanding of how structured psychosocial stress affects the mind-body interaction, and, ultimately, writes a literal image of that structure upon that interaction. This process begins in utero or early childhood, and determines a life-course trajectory to inherently comorbid disease.

We begin with a recitation of some formally cognitive submodules of human biology, in a large sense, which we believe interact both with each other and with structured psychosocial stress. Next we explore cognition as 'language', and infer the existence of a 'generalized cognitive homunculus' analogous to that explored by Cohen (2000) as the basis of autoimmune disease. Ultimately we propose a model based on autoimmune disease to account for a life trajectory of chronic comorbid psychiatric/physical disorder as involving a usually transient excited state of that homunculus which becomes a pathologically and recurrently 'permanent' zero-mode.

What we attempt is, in fact, surprisingly consonant with a current of mainstream thinking in cognitive science, what Adams (2003) characterizes as "the informational turn in philosophy", i.e. the relatively recent application of information-theoretic perspectives to the long, arduous, intellectual quest to understand 'mind'. One of the first comprehensive syntheses was that of Dretske (1981, 1988, 1992, 1993, 1994), who put the matter thus (Dretske, 1994: 59-70):

“The mind can be viewed as an information-driven control system. To make this work, the idea of information must be operationalized in such a way as to give semantic properties (meaning, content) a role in the explanation of system behavior. This can be achieved by exploiting a statistical concept - mutual information - from communication theory. On this interpretation, some of the behavior of information-driven control systems is causally explained by the statistical correlations that exist between internal states and the external conditions about which they carry information...

[A]lthough the chief concern of communication theory is the statistical properties of signals and channels, not the semantic information (if any) that these signals happen to carry over the channels, the statistical properties turn out to be relevant to what semantic information a signal can carry. Unless there is a statistically reliable channel of communication between [source] *S* and [receiver] *R*, the signals reaching *R* from *S* cannot indicate what is happening at *S*... No signal can carry semantic information... unless the channel over which the signal arrives satisfies the appropriate statistical constraints of communication theory...

Communication theory can be interpreted as telling one something important about the conditions that are needed for the transmission of information as ordinarily understood, about what it takes for the transmission of semantic information. This has tempted people... to exploit [information theory] in semantic and cognitive studies, and thus, in the philosophy of mind...

If a semantic engine is a system whose performance is explained, not simply by the physical events occurring in it, but by the meaning of information that these events carry, then some systems, those capable of [learning], are semantic engines. The control system in such engines is an information-driven control system. Such systems are, in this sense and to this extent, minded.”

That is, at very least, information theory explores the necessary conditions for cognitive process.

Adams (2003: 488-489) describes Dretske’s contributions as follows:

“It is not uncommon to think that information is a commodity generated by things with minds. Let’s say that a naturalized account puts matters the other way around, viz. it says that minds are things that come into being by purely natural causal means of exploiting the information in their environments. This is the approach taken by Dretske as he tried consciously to unite the cognitive sciences around the well-understood mathematical theory of communication...”

Here we redirect attention from the informational content or ‘meaning’ of individual symbols, i.e. the province of semantics, back to the statistical properties of long trains of symbols emitted by an ‘information source’. As Dretske clearly saw, this allows scientific inference on the necessary conditions for cognitive process, but now in the asymptotic limit of very long sequences of output, which is quite precisely the home ground of classic communication theory. This redirection, we claim, will provide, along with some further modest asymptotic machinery imported from

statistical physics, a sufficient basis for understanding the role of structured psychosocial stress in the etiology of developmental cognitive disorder, in a large sense.

2. SOME COGNITIVE MODULES OF HUMAN BIOLOGY

Immune function

Atlan and Cohen (1998) have proposed an information-theoretic cognitive model of immune function and process, a paradigm incorporating cognitive pattern recognition-and-response behaviors analogous to those of the central nervous system. This work follows in a very long tradition of speculation on the cognitive properties of the immune system (e.g. Tauber, 1998; Podolsky and Tauber, 1997; Grossman, 1989, 1992 a, b, 1993, 2000).

From the Atlan/Cohen perspective, the meaning of an antigen can be reduced to the type of response the antigen generates. That is, the meaning of an antigen is functionally defined by the response of the immune system. The meaning of an antigen to the system is discernible in the type of immune response produced, not merely whether or not the antigen is perceived by the receptor repertoire. Because the meaning is defined by the type of response there is indeed a response repertoire and not only a receptor repertoire.

To account for immune interpretation Cohen (1992, 2000) has reformulated the cognitive paradigm for the immune system. The immune system can respond to a given antigen in various ways, it has 'options.' Thus the particular response we observe is the outcome of internal processes of weighing and integrating information about the antigen.

In contrast to Burnet's view of the immune response as a simple reflex, it is seen to exercise cognition by the interpolation of a level of information processing between the antigen stimulus and the immune response. A cognitive immune system organizes the information borne by the antigen stimulus within a given context and creates a format suitable for internal processing; the antigen and its context are transcribed internally into the 'chemical language' of the immune system.

The cognitive model suggests a language metaphor to describe immune communication by a string of chemical signals. This metaphor is apt because the human and immune languages can be seen to manifest several similarities such as syntax and abstraction. Syntax, for example, enhances both linguistic and immune meaning. Although individual words and even letters can have their own meanings, an unconnected subject or an unconnected predicate will tend to mean less than does the sentence generated by their connection.

The immune system creates a 'language' by linking two ontogenetically different classes of molecules in a syntactical fashion. One class of molecules are the T and B cell receptors for antigens. These molecules are not inherited, but are somatically generated in each individual. The other class of molecules responsible for internal information processing is encoded in the individual's germline. Meaning, the chosen type of immune response, is the outcome of the concrete connection between the antigen subject and the germline predicate signals. The transcription of the antigens into processed peptides embedded in a context of germline ancillary signals constitutes

the functional ‘language’ of the immune system. Despite the logic of clonal selection, the immune system does not respond to antigens as they are, but to abstractions of antigens-in-context.

Tumor control

We propose that the next cognitive submodule after the immune system is a tumor control mechanism which may include ‘immune surveillance’, but clearly transcends it. Nunney (1999) has explored cancer occurrence as a function of animal size, suggesting that in larger animals, whose lifespan grows as about the 4/10 power of their cell count, prevention of cancer in rapidly proliferating tissues becomes more difficult in proportion to size. Cancer control requires the development of additional mechanisms and systems to address tumorigenesis as body size increases; a synergistic effect of cell number and organism longevity. Nunney (1999, p. 497) concludes:

“This pattern may represent a real barrier to the evolution of large, long-lived animals and predicts that those that do evolve ... have recruited additional controls [over those of smaller animals] to prevent cancer.”

Different tissues may have evolved markedly different tumor control strategies. All of these, however, are likely to be energetically expensive, permeated with different complex signaling strategies, and subject to a multiplicity of reactions to signals, including those related to psychosocial stress. Forlenza and Baum (2000) explore the effects of stress on the full spectrum of tumor control, ranging from DNA damage and control, to apoptosis, immune surveillance, and mutation rate. Elsewhere (R. Wallace *et al.*, 2003) we argue that this elaborate tumor control strategy, particularly in large animals, must be at least as cognitive as the immune system itself, which is one of its components. That is, some comparison must be made with an internal picture of a ‘healthy’ cell, and a choice made as to response: none, attempt DNA repair, trigger programmed cell death, engage in full-blown immune attack. This is, from the Atlan/Cohen perspective, the essence of cognition.

The HPA axis

The hypothalamic-pituitary-adrenal (HPA) axis, a part of the general ‘flight-or-fight’ system including the sympathoadrenomedullary system (SAM), is clearly cognitive in the Atlan/Cohen sense. Upon recognition of a new perturbation in the surrounding environment, memory and brain or emotional cognition evaluate and choose from several possible responses: no action needed, flight, fight, helplessness (i.e. flight or fight needed, but not possible). Upon appropriate conditioning, the HPA system, in coordination with the SAM axis, is able to accelerate the decision process, much as the immune system has a more efficient response to second pathogenic challenge once the initial infection has become encoded in immune memory. Certainly ‘hyperreactivity’ in the context of post-traumatic stress disorder (PTSD) is a well known example. Chronic HPA axis activation is deeply implicated in visceral obesity leading to diabetes and heart disease, via the leptin/cortisol diurnal cycle (e.g. Bjorntorp, 2001; Wallace and Wallace, 2003).

Blood pressure regulation

Rau and Elbert (2001) review much of the literature on blood pressure regulation, particularly the interaction between baroreceptor activation and central nervous function. We paraphrase some of their analysis. The essential point, of course, is that unregulated blood pressure would be quickly fatal in any animal with a circulatory system, a matter as physiologically fundamental as tumor control. Much work over the years has elucidated some of the mechanisms involved. Increase in arterial blood pressure stimulates the arterial baroreceptors which in turn elicit the baroreceptor reflex, causing a reduction in cardiac output and in peripheral resistance, returning pressure to its original level. The reflex, however, is not actually this simple. It may be inhibited through peripheral processes, for example under conditions of high metabolic demand. In addition, higher brain structures modulate this reflex arc, for instance when threat is detected and fight or flight responses are being prepared. This suggests, then, that blood pressure control cannot be a simple reflex, but is a broad and actively cognitive modular system which compares a set of incoming signals with an internal reference configuration, and then chooses an appropriate physiological level of blood pressure from a large repertory of possible levels. That is, it is a cognitive process in the Atlan/Cohen sense. The baroreceptors and the baroreceptor reflex are, from this perspective, only one set of a complex array of components making up a larger and more comprehensive cognitive blood pressure regulatory module.

Emotion

Thayer and Lane (2000) summarize the case for what can be described as a cognitive emotional process. Emotions, in their view, are an integrative index of individual adjustment to changing environmental demands, an organismal response to an environmental event that allows rapid mobilization of multiple subsystems. Emotions are the moment-to-moment output of a continuous sequence of behavior, organized around biologically important functions. These 'lawful' sequences have been termed 'behavioral systems' by Timberlake (1994).

Emotions are self-regulatory responses that allow the efficient coordination of the organism for goal-directed behavior. Specific emotions imply specific eliciting stimuli, specific action tendencies including selective attention to relevant stimuli, and specific reinforcers. When the system works properly, it allows for flexible adaptation of the organism to changing environmental demands. Thus an emotional response represents a *selection* of an appropriate response and the inhibition of other less appropriate responses from a more or less broad behavioral repertoire of possible responses. Such 'choice', we will show, leads directly to something closely analogous to the Atlan and Cohen language metaphor.

Damasio (1998) concludes that emotion is the most complex expression of homeostatic regulatory systems. The results of emotion serve the purpose of survival even in nonminded organisms, operating along dimensions of approach or aversion, of appetite or withdrawal. Emotions protect the subject organism by avoiding predators or scaring them away, or by leading the organism to food and sex. Emotions often operate as a basic mechanism for making decisions without the labors of reason, that is, without resorting to deliberated considerations of facts, options, outcomes, and rules of logic. In humans learning can pair emotion with facts which describe the

premises of a situation, the option taken relative to solving the problems inherent in a situation, and perhaps most importantly, the outcomes of choosing a certain option, both immediately and in the future. The pairing of emotion and fact remains in memory in such a way that when the facts are considered in deliberate reasoning when a similar situation is revisited, the paired emotion or some aspect of it can be reactivated. The recall, according to Damasio, allows emotion to exert its pairwise qualification effect, either as a conscious signal or as nonconscious bias, or both. In both types of action the emotions and the machinery underlying them play an important regulatory role in the life of the organism. This higher order role for emotion is still related to the needs of survival, albeit less apparently.

Thayer and Friedman (2002) argue, from a dynamic systems perspective, that failure of what they term 'inhibitory processes' which, among other things, direct emotional responses to environmental signals, is an important aspect of psychological and other disorders. Sensitization and inhibition, they claim, 'sculpt' the behavior of an organism to meet changing environmental demands. When these inhibitory processes are dysfunctional - choice fails - pathology appears at numerous levels of system function, from the cellular to the cognitive.

Thayer and Lane (2000) also take a dynamic systems perspective on emotion and behavioral subsystems which, in the service of goal-directed behavior and in the context of a behavioral system, they see organized into coordinated assemblages that can be described by a small number of control parameters. This resembles the factors of factor analysis, revealing the latent structure among a set of questionnaire items thereby reducing or mapping the higher dimensional item space into a lower dimensional factor space. In their view, emotions may represent preferred configurations in a larger 'state-space' of a possible behavioral repertoire of the organism. From their perspective, disorders of affect represent a condition in which the individual is unable to select the appropriate response, or to inhibit the inappropriate response, so that the response selection mechanism is somehow corrupted.

Gilbert (2001) suggests that a canonical form of such 'corruption' is the excitation of modes that, in other circumstances, represent 'normal' evolutionary adaptations, a matter to which we will return at some length below.

Conscious 'rational thought'

Although a Cartesian dichotomy between 'rational thought' and 'emotion' may be increasingly suspect, nonetheless humans, like many other animals, do indeed conduct conscious individual rational cognitive decision-making as most of us would commonly understand it. Various forms of dementia involve characteristic patterns of degradation in that ability. Dehaene and Naccache (2001) describe the global neuronal workspace model of consciousness, and our own extension of that model is available elsewhere (Wallace, 2004).

Sociocultural network

Humans are particularly noted for a hypersociality which inevitably enmeshes us all in group processes of decision, i.e. collective cognitive behavior within a social network, tinged by an embedding shared culture. For humans, culture is truly

fundamental. Durham (1991) argues that genes and culture are two distinct but interacting systems of inheritance within human populations. Information of both kinds has influence, actual or potential, over behaviors, which creates a real and unambiguous symmetry between genes and phenotypes on the one hand, and culture and phenotypes, on the other. Genes and culture are best represented as two parallel lines or tracks of hereditary influence on phenotypes.

Much of hominid evolution can be characterized as an interweaving of genetic and cultural systems. Genes came to encode for increasing hypersociality, learning, and language skills. The most successful populations displayed increasingly complex structures that better aided in buffering the local environment (e.g. Bonner, 1980).

Successful human populations seem to have a core of tool usage, sophisticated language, oral tradition, mythology, music, and decision making skills focused on relatively small family/extended family social network groupings. More complex social structures are built on the periphery of this basic object (e.g. Richerson and Boyd, 1995). The human species' very identity may rest on its unique evolved capacities for social mediation and cultural transmission. These are particularly expressed through the cognitive decision making of small groups facing changing patterns of threat and opportunity, processes in which we are all embedded and all participate.

3. COGNITION AS 'LANGUAGE'

Atlan and Cohen (1998) argue that the essence of cognition is comparison of a perceived external signal with an internal, learned picture of the world, and then, upon that comparison, the choice of one response from a much larger repertoire of possible responses. We make a very general model of this process.

Pattern recognition-and-response, as we characterize it, proceeds by convoluting an incoming external 'sensory' signal with an internal 'ongoing activity' - the 'learned picture of the world' - and, at some point, triggering an appropriate action from a larger set of possible actions, based on a decision that the pattern of sensory activity requires a response. We need not specify how the pattern recognition system is 'trained', and hence we adopt a weak model, regardless of learning paradigm, which can itself be more formally described by the Rate Distortion Theorem. We will, fulfilling Atlan and Cohen's (1998) criterion of meaning-from-response, define a language's contextual meaning entirely in terms of system output.

The model, an extension of that presented in Wallace (2000), is as follows. A pattern of 'sensory' input, say an ordered sequence y_0, y_1, \dots , is mixed in a systematic way with internal 'ongoing' activity, the sequence w_0, w_1, \dots , to create a path of composite signals $x = a_0, a_1, \dots, a_n, \dots$, where $a_j = f(y_j, w_j)$ for a function F . An explicit example will be given below. This path is then fed into a highly nonlinear 'decision oscillator' which generates an output $h(x)$ that is an element of one of two (presumably) disjoint sets B_0 and B_1 . We take

$$B_0 \equiv b_0, \dots, b_k,$$

$$B_1 \equiv b_{k+1}, \dots, b_m.$$

Thus we permit a graded response, supposing that if

$$h(x) \in B_0$$

the pattern is not recognized, and if

$$h(x) \in B_1$$

the pattern is recognized and some action b_j , $k+1 \leq j \leq m$ takes place.

We are interested in composite paths x which trigger pattern recognition-and-response exactly once. That is, given a fixed initial state a_0 , such that $h(a_0) \in B_0$, we examine all possible subsequent paths x beginning with a_0 and leading exactly once to the event $h(x) \in B_1$. Thus $h(a_0, \dots, a_j) \in B_0$ for all $j < m$, but $h(a_0, \dots, a_m) \in B_1$.

For each positive integer n let $N(n)$ be the number of paths of length n which begin with some particular a_0 having $h(a_0) \in B_0$ and lead to the condition $h(x) \in B_1$. We shall call such paths ‘meaningful’ and assume $N(n)$ to be considerably less than the number of all possible paths of length n ; pattern recognition-and-response is comparatively rare. We further assume that the finite limit

$$H \equiv \lim_{n \rightarrow \infty} \frac{\log[N(n)]}{n}$$

both exists and is independent of the path x . We will, not surprisingly, call such a cognitive process *ergodic*.

Note that disjoint partition of ‘state space’ may be possible according to sets of states which can be connected by ‘meaningful’ paths, leading to a ‘natural’ coset algebra of the system, a matter of some importance we will not pursue here, but which appears significantly in other contexts.

We may thus define an ergodic information source \mathbf{X} associated with stochastic variates X_j having joint and conditional probabilities $P(a_0, \dots, a_n)$ and $P(a_n | a_0, \dots, a_{n-1})$ such that appropriate joint and conditional Shannon uncertainties may be defined which satisfy the relations (Cover and Thomas, 1991; Ash, 1990)

$$\begin{aligned} H[\mathbf{X}] &= \lim_{n \rightarrow \infty} \frac{\log[N(n)]}{n} = \\ &= \lim_{n \rightarrow \infty} H(X_n | X_0, \dots, X_{n-1}) = \\ &= \lim_{n \rightarrow \infty} \frac{H(X_0, \dots, X_n)}{n}. \end{aligned} \quad (1)$$

We say this information source is *dual* to the ergodic cognitive process.

The Shannon-McMillan Theorem provides a kind of ‘law of large numbers’ and permits definition of the Shannon uncertainties in terms of cross-sectional sums of the form

$$H = -\sum P_k \log[P_k],$$

where the P_k are taken from a probability distribution, so that $\sum P_k = 1$. Again, Cover and Thomas (1991) or Ash (1990) provide algebraic details.

It is important to recognize that different ‘languages’ will be defined by different divisions of the total universe of possible responses into various pairs of sets B_0 and B_1 , or by requiring more than one response in B_1 along a path. Like the use of different distortion measures in the Rate Distortion Theorem (e.g. Cover and Thomas, 1991), however, it seems obvious that the underlying dynamics will all be qualitatively

similar. Nonetheless, dividing the full set of possible responses into the sets B_0 and B_1 may itself require ‘higher order’ cognitive decisions by another module or modules, suggesting the necessity of ‘choice’ within a more or less broad set of possible ‘languages of thought’. This would directly reflect the need to ‘shift gears’ according to the different challenges faced by the organism, either cross-sectionally at a particular time, or developmentally as it matures, accounting for ‘critical periods’ in the onset of developmental disorder. This is a fundamental matter to which we will return. A critical problem then becomes the choice of a ‘normal’ zero-mode language among a very large set of possible languages representing the (hyper or hypo) ‘excited states’ accessible to the system. We explore this point below in various ways.

In sum, meaningful paths, creating an inherent grammar and syntax, have been defined entirely in terms of system response as Atlan and Cohen (1998) propose.

We can apply this formalism to the stochastic neuron in a neural network: A series of inputs y_i^j , $i = 1, \dots, m$ from m nearby neurons at time j to the neuron of interest is convoluted with ‘weights’ w_i^j , $i = 1, \dots, m$, using an inner product

$$a_j = \mathbf{y}^j \cdot \mathbf{w}^j \equiv \sum_{i=1}^m y_i^j w_i^j \quad (2)$$

in the context of a ‘transfer function’ $f(\mathbf{y}^j \cdot \mathbf{w}^j)$ such that the probability of the neuron firing and having a discrete output $z^j = 1$ is $P(z^j = 1) = f(\mathbf{y}^j \cdot \mathbf{w}^j)$. Thus the probability that the neuron does not fire at time j is just $1 - P$. In the usual terminology the m values y_i^j constitute the ‘sensory activity’ and the m weights w_i^j the ‘ongoing activity’ at time j , with $a_j = \mathbf{y}^j \cdot \mathbf{w}^j$ and the path $x \equiv a_0, a_1, \dots, a_n, \dots$. A more elaborate example is given in Wallace (2002a).

A little work leads to a standard neural network model in which the network is trained by appropriately varying \mathbf{w} through least squares or other error minimization feedback. This can be shown to replicate rate distortion arguments. That is, we can use the error definition to define a distortion function which measures the difference between the training pattern y and the network output \hat{y} as a function, for example, of the inverse number of training cycles, K . As we will discuss in another context, ‘learning plateau’ behavior emerges naturally as a phase transition in the mutual information $I(Y, \hat{Y})$ driven by the parameter K .

Thus we will ultimately parametrize the information source uncertainty of the dual information source to a cognitive pattern recognition-and-response with respect to one or more variates, writing, e.g. $H[\mathbf{K}]$, where $\mathbf{K} \equiv (K_1, \dots, K_s)$ represents a vector in a parameter space. Let the vector \mathbf{K} follow some path in time, i.e. trace out a generalized line or surface $\mathbf{K}(t)$. We will, following the argument of Wallace (2002b), assume that the probabilities defining H for the most part closely track changes in $\mathbf{K}(t)$. That is, along a particular ‘piece’ of a path in parameter space, the information source remains as close to memoryless and ergodic as is needed for the mathematics to work. Between pieces, as discussed in the following section, we impose phase transition characterized by a kind of renormalization symmetry, in the sense of Wilson (1971). See Binney *et al.* (1986) for a more complete discussion. Wallace *et al.* (2003a) and R. Wallace and R.G. Wallace (2003) present detailed calculations of ‘biological’ renormalizations and ‘universality class tuning’ which take the theory well beyond simple physical analogs.

We will call such an information source ‘adiabatically piecewise memoryless ergodic’ (APME). The ergodic nature of the information sources is a generalization of the ‘law of large numbers’ and implies that the long-time averages we will need to calculate can, in fact, be closely approximated by averages across the probability spaces of those sources.

Our treatment does not preclude the existence of cognitive processes or submodules which may not have appropriate dual information sources. We cannot, however, fit them easily into our development, although Wallace (2003b) has begun to explore possible extension of the theory to a certain class of ‘nearly ergodic’ information sources.

4. INTERACTING INFORMATION SOURCES: ‘SOCIOCULTURAL PSYCHONEUROIMMUNOLOGY’

We suppose that the behavior of a cognitive subsystem can be represented by a sequence of ‘states’ in time, the ‘path’ $x \equiv x_0, x_1, \dots$. Similarly, we assume an external signal of ‘structured psychosocial stress’ can also be represented by a path $y \equiv y_0, y_1, \dots$. These paths are, however, both very highly structured and, within themselves, are serially correlated. They can, we assume, be represented by ‘information sources’ \mathbf{X} and \mathbf{Y} . The cognitive process and external stressors interact, so that these two sequences of states are not independent, but are jointly serially correlated. We can, then, define a path of sequential pairs as $z \equiv (x_0, y_0), (x_1, y_1), \dots$

The essential content of the Joint Asymptotic Equipartition Theorem is that the set of joint paths z can be partitioned into a relatively small set of high probability which is termed *jointly typical*, and a much larger set of vanishingly small probability. Further, according to the JAEPT, the *splitting criterion* between high and low probability sets of pairs is the mutual information

$$I(X, Y) = H(X) - H(X|Y) = H(X) + H(Y) - H(X, Y) \quad (3)$$

where $H(X)$, $H(Y)$, $H(X|Y)$ and $H(X, Y)$ are, respectively, the Shannon uncertainties of X and Y , their conditional uncertainty, and their joint uncertainty. See Cover and Thomas (1991) or Ash (1990) for mathematical details. As stated above, the Shannon-McMillan Theorem and its variants permit expression of the various uncertainties in terms of cross sectional sums of terms of the form $-\mathcal{P}_k \log[\mathcal{P}_k]$ where the \mathcal{P}_k are appropriate direct or conditional probabilities. Similar approaches to neural process have been recently adopted by Dimitrov and Miller (2001).

In this formulation the high-probability pairs of paths are all equiprobable and if $N(n)$ is the number of jointly typical pairs of length n , then, according to the Shannon-McMillan Theorem and its ‘joint’ variants,

$$I(X, Y) = \lim_{n \rightarrow \infty} \frac{\log[N(n)]}{n}. \quad (4)$$

Generalizing the earlier language-on-a-network models of R. Wallace and R. Wallace (1998, 1999), we suppose there is a ‘coupling parameter’ P representing the degree of linkage between the cognitive system of interest and the structured ‘language’ of external signals and stressors, and set $K = 1/P$, following the development of those earlier studies. Then we have

$$I(K) = \lim_{n \rightarrow \infty} \frac{\log[\mathcal{N}(K, n)]}{n}.$$

The essential ‘homology’ between information theory and statistical mechanics lies in the similarity of this expression with the infinite volume limit of the free energy density. If $Z(K)$ is the statistical mechanics partition function derived from the system’s Hamiltonian, then the free energy density is determined by the relation

$$F(K) = \lim_{V \rightarrow \infty} \frac{\log[Z(K)]}{V}. \quad (5)$$

F is the free energy density, V the system volume and $K = 1/T$, where T is the system temperature.

We and others argue at some length (e.g. R. Wallace and R. Wallace, 1998, 1999; Wallace, 2000; Rojdestvensky and Cottam, 2000; Feynman, 1996) that this is indeed a systematic mathematical homology which, we contend, permits importation of renormalization symmetry into information theory. Imposition of invariance under renormalization on the mutual information splitting criterion $I(X, Y)$ implies the existence of phase transitions analogous to learning plateaus or punctuated evolutionary equilibria in the relations between cognitive mechanism and external perturbation. An extensive mathematical treatment of these ideas is presented elsewhere. Again, R. Wallace and R.G. Wallace, (2003) and Wallace *et al.* (2003a) provide detailed examples of ‘biological’, as opposed to simple physical, models. These involve elaborate renormalization schemes, and even ‘universality class tuning’ in which characteristic parameters which are constant in physical systems are themselves subject to higher order selection in organisms.

From a the more limited perspective of the Rate Distortion Theorem, a selective corollary of the Shannon-McMillan Theorem, we can view the onset of a punctuated interaction between the cognitive mechanism and external stressors as the literal writing of distorted image of those stressors upon cognition:

Suppose that two (piecewise, adiabatically memoryless) ergodic information sources \mathbf{Y} and \mathbf{B} begin to interact, to ‘talk’ to each other, i.e. to influence each other in some way so that it is possible, for example, to look at the output of \mathbf{B} - strings b - and infer something about the behavior of \mathbf{Y} from it - strings y . We suppose it possible to define a retranslation from the B-language into the Y-language through a deterministic code book, and call $\hat{\mathbf{Y}}$ the translated information source, as mirrored by \mathbf{B} .

Define some distortion measure comparing paths Y to paths \hat{y} , $d(y, \hat{y})$ (Cover and Thomas, 1991). We invoke the Rate Distortion Theorem’s mutual information $I(Y, \hat{Y})$, which is the splitting criterion between high and low probability pairs of paths. Impose, now, a parametrization by an inverse coupling strength K , and a renormalization symmetry representing the global structure of the system coupling.

Extending the analyses, triplets of sequences, Y_1, Y_2, Z , for which one in particular, here Z , is the ‘embedding context’ affecting the other two, can also be divided by a splitting criterion into two sets, having high and low probabilities respectively. The probability of a particular triplet of sequences is then determined by the conditional probabilities

$$P(Y_1 = y^1, Y_2 = y^2, Z = z) = \prod_{j=1}^n P(y_j^1 | z_j) P(y_j^2 | z_j) P(z_j). \quad (6)$$

That is, Y_1 and Y_2 are, in some measure, driven by their interaction with Z .

For large n the number of triplet sequences in the high probability set will be determined by the relation (Cover and Thomas, 1991, p. 387)

$$N(n) \propto \exp[nI(Y_1; Y_2 | Z)], \quad (7)$$

where the splitting criterion is given by

$$I(Y_1; Y_2 | Z) \equiv H(Z) + H(Y_1 | Z) + H(Y_2 | Z) - H(Y_1, Y_2, Z).$$

We can then examine mixed cognitive/adaptive phase transitions analogous to learning plateaus (Wallace, 2002b) in the splitting criterion $I(Y_1, Y_2 | Z)$. Note that our results are almost exactly parallel to the Eldredge/Gould model of evolutionary punctuated equilibrium (Eldredge, 1985; Gould, 2002).

We can, for the purposes of this work, extend this model to any number of interacting information sources, Y_1, Y_2, \dots, Y_s conditional on an external context Z in terms of a splitting criterion defined by

$$I(Y_1; \dots; Y_s | Z) = H(Z) + \sum_{j=1}^s H(Y_j | Z) - H(Y_1, \dots, Y_s, Z), \quad (8)$$

where the Shannon uncertainties $H(\dots)$ are determined by the appropriate direct and conditional probabilities.

5. THE GENERALIZED COGNITIVE HOMUNCULUS AND ITS RETINA: RESPONDING TO SUDDEN CHANGE

Cohen (2000) argues at some length for the existence of an ‘immunological homunculus’, i.e. the immune system’s own perception of the body as a whole. The particular utility of such a construct, in his view, is that sensing perturbations in that self-image can serve as an early warning sign of pending necessary inflammatory response: expressions of tumorigenesis, acute or chronic infection, parasitization, and the like. Thayer and Lane (2000) argue something analogous for emotional response as a quick internal index of larger patterns of threat or opportunity.

It seems obvious that the collection of interacting cognitive submodules we have explored above must also have a coherent internal self-image of the state of the mind-and-body and its social relationships. Such a coherent structure would be analogous to the rapidly converging ‘hall of mirrors’ of the immune system’s idiotypic network involving auto- and antiauto- immune responses. This inferred picture, at the individual level, we term the ‘generalized cognitive homunculus’ (GCH).

We are particularly interested in this structure’s relation to imposed patterns of psychosocial stress. Let us suppose we cannot measure either stress or cognitive submodule function directly. Rather, we can determine the concentrations of hormones, neurotransmitters, certain cytokines, and other biomarkers, or else macroscopic behaviors, beliefs, feelings, and other responses associated with the function of cognitive submodules according to some ‘natural’ time frame inherent to the system. This would typically be the circadian cycle in both men and women, and the hormonal cycle in premenopausal women. Suppose, in the absence of extraordinary ‘meaningful’ psychosocial stress, we measure a series of n biomarker

concentrations, behavioral characteristics, and other indices at time t which we represent as an n -dimensional vector X_t . Suppose we conduct a number of experiments, and create a regression model so that we can, in the absence of perturbation, write, to first order, the markers at time $t + 1$ in terms of those at time t using a matrix equation of the form

$$X_{t+1} \approx \mathbf{R}X_t, \quad (9)$$

where \mathbf{R} is an n -by- n matrix of regression coefficients.

We wish to generalize this model, attempting to characterize the GCH response to short-term perturbation - not the effects of long-lasting structured psychosocial stress. Let \mathbf{R}_0 be the regression matrix of an n -by- n ‘zero reference state’ of the GCH, and let $\delta\mathbf{R}_t$ be taken as representing a perturbation from that underlying state. Then, if X_t is the n -by-1 matrix of biomarker measurements at time T , we have for time $t + 1$,

$$X_{t+1} = (\mathbf{R}_0 + \delta\mathbf{R}_{t+1})X_t,$$

Next we impose a (Jordan block) diagonalization in terms of the matrix of (generally *nonorthogonal*) eigenvectors \mathbf{Q}_0 of the zero reference state \mathbf{R}_0 , obtaining, for an initial condition which is an eigenvector $Y_t \equiv Y_k$ of \mathbf{R}_0 ,

$$\begin{aligned} Y_{t+1} &= (\mathbf{J}_0 + \delta\mathbf{J}_{t+1})Y_k = \lambda_k Y_k + \delta Y_{t+1} = \\ &\lambda_k Y_k + \sum_{j=1}^n a_j Y_j \end{aligned} \quad (10)$$

where \mathbf{J}_0 is a (block) diagonal matrix as above, $\delta\mathbf{J}_{t+1} \equiv \mathbf{Q}_0 \delta\mathbf{R}_{t+1} \mathbf{Q}_0^{-1}$, and δY_{t+1} has been expanded in terms of a spectrum of the eigenvectors of \mathbf{R}_0 , with

$$|a_j| \ll |\lambda_k|, |a_{j+1}| \ll |a_j|. \quad (11)$$

The essential point is that, provided \mathbf{R}_0 has been properly ‘tuned’, so that this condition is true, the first few terms in the spectrum of the pleiotropic iteration of the eigenstate will contain almost all of the essential information about the perturbation, i.e. most of the variance. We envision this as similar to the detection of color in the optical retina, where three overlapping non-orthogonal ‘eigenmodes’ of response suffice to characterize a vast array of color sensations. Here, if a concise spectral expansion is possible, a very small number of (typically nonorthogonal) ‘generalized cognitive eigenmodes’ permit characterization of a vast range of external perturbations, and rate distortion constraints become very manageable indeed. Thus GCH responses, the spectrum of excited eigenmodes of \mathbf{R}_0 , provided it is properly tuned, can be a very accurate and precise gauge of environmental perturbation.

The choice of zero reference state \mathbf{R}_0 , i.e. the ‘base state’ from which perturbations are measured, is, we claim, a highly nontrivial task necessitating a specialized apparatus.

This is a critical matter. According to current theory, the adapted human mind functions through the action and interaction of distinct mental modules which evolved fairly rapidly to help address special problems of environmental and social selection pressure faced by our Pleistocene ancestors (e.g. Barkow *et al.*, 1992). Here we have postulated the necessity of other physiological and social cognitive modules. As is well known in computer engineering, calculation by specialized submodules, e.g. numeric processor chips, can be a far more efficient means of solving particular well-

defined classes of problems than direct computation by a generalized system. We suggest, then, that our generalized cognition has evolved specialized submodules to speed the address of certain commonly recurring challenges.

We argue that identification of the ‘normal’ state of the GCH - generalized cognition’s self-image of the body and its social relationships - is a difficult matter requiring a dedicated cognitive submodule within overall generalized cognition. This is essentially because, for the vast majority of information systems, unlike mechanical systems there are no ‘restoring springs’ whose low energy state automatically identifies equilibrium. That is, relatively speaking, all states of the GCH are ‘high energy’ or high information states. Thus active comparison must be made of the state of the GCH with some stored internal reference picture, and a decision made about whether to reset to zero, which is a cognitive process. We further speculate that the complexity of such a submodule must also follow something like Nunney’s power law with animal size, as the overall generalized cognition and its image of the self, become increasingly complicated with rising number of cells and levels of linked cognition.

Failure of that cognitive submodule results in identification of a usually transient activated state of the GCH as ‘normal’, triggering the collective patterns of systemic activation (possibly including persistent underactivation) which constitute certain comorbid mental and chronic physical disorders. This would result in a relatively small number of characteristic ‘eigenforms’ of comorbidity, which would typically become more mixed with increasing disorder.

In sum, since such ‘zero mode identification’ (ZMI) is a (presumed) cognitive submodule of overall generalized cognition, it involves convoluting incoming ‘sensory’ with ‘ongoing’ internal memory data in choosing the zero state, i.e. defining R_0 . The dual information source defined by this cognitive process can then interact in a punctuated manner with ‘external information sources’ according to the Rate Distortion and related arguments above. From a RDT perspective, then, those external information sources literally write a distorted image of themselves onto the ZMI, often in a punctuated manner: (relatively) sudden onset of a developmental trajectory to comorbid mental disorders and chronic physical disease.

Different systems of external signals - including but not limited to structured psychosocial stress - will, presumably, write different characteristic images of themselves onto the ZMI cognitive submodule, i.e. trigger different patterns of comorbid mental disorder and chronic diseases.

Elsewhere (R. Wallace, 2003a) we speculate that patterns of autoimmune disease are likely to be related to both circadian and hormonal cycles, factors which may come into play in comorbidity of more general mental and chronic physical disorder.

Further theoretical development would introduce the ‘generalized Onsager relation’ analysis of gradient effects in driving parameters which affects system behavior between phase transitions (e.g. Wallace, 2002a). These extensions are not trivial.

6. DISCUSSION

To recapitulate, if Y represents the information source dual to ‘zero mode identification’ in generalized cognition, and if Z is the information source

characterizing structured psychosocial stress, which serves as an embedding context, the ‘mutual information’ between them

$$I(Y; Z) = H(Y) - H(Y|Z)$$

serves as a splitting criterion for pairs of linked paths of states.

We suppose it possible to parametrize the coupling between these interacting information sources by some ‘inverse temperature’, K , writing

$$I(Y; Z) = I[K],$$

with structured psychosocial stress as the embedding context.

Invocation of the mathematical homology between equations (4) and (5) permits imposition of renormalization formalism (R. Wallace and R.G. Wallace, 2003; Wallace *et al.*, 2003a) resulting in punctuated phase transition depending on K .

Socioculturally constructed and structured psychosocial stress, in this model having both ‘grammar’ and ‘syntax’, can be viewed as entraining the function of zero mode identification when the coupling with stress exceeds a threshold. More than one threshold appears likely, accounting in a sense for the often staged nature of ‘environmentally caused’ disorders. These should result in a series of collective, but highly systematic, ‘tuning failures’ which, in the Rate Distortion sense, represents a literal image of the structure of imposed psychosocial stress written upon the ability of the GCH to characterize a ‘normal’ mode of excitation. The result is that a mixed atypical and usually transient state becomes permanent, producing comorbid mental and chronic physical disorder. As discussed above, this process may have both cross-sectional and longitudinal structure, with the latter accounting for ‘critical periods’ in the onset of developmental disorders. We provide a number of examples.

Coronary heart disease (CHD) is already understood as a disease of development, which begins *in utero*. Work by Barker and colleagues (Barker *et al.*, 2002; Osmond and Barker, 2000; Godfrey and Barker, 2001) suggests that those who develop CHD grow differently from others, both in utero and during childhood. Slow growth during fetal life and infancy is followed by accelerated weight gain in childhood, setting a life history trajectory for CHD, type II diabetes, hypertension, and, of course, obesity. Barker (2002) concludes that slow fetal growth might also heighten the body’s stress responses and increase vulnerability to poor living conditions later in life. Thus, in his view, CHD is a developmental disorder that originates through two widespread biological phenomena, developmental plasticity and compensatory growth. This is a conclusion consistent with the work of Smith *et al.* (1998), who found that deprivation in childhood influences risk of mortality from CHD in adulthood, although an additive influence of adult circumstances is seen in such cases.

Much of the CHD work particularly implicates certain kinds of hypertension as a developmental disorder. As Eriksson *et al.* (2000, p. 790) put the matter,

“The association between low birth weight and raised blood pressure in later life has now been reported in more than 50 published studies of men, women, and children. It has been shown to result from retarded fetal growth rather than premature birth. The ‘fetal origins’ hypothesis proposes that the association reflects permanent resetting of blood pressure by undernutrition *in utero*.”

With regard to asthma, Wright *et al.* (1998) find prospective epidemiological studies showing that the newborn period is dominated by Th2 reactivity in response to

allergens, and it is also evident that Th1 memory cells selectively develop shortly after birth, and persist into adulthood in non-atopic subjects. For most children who become allergic or asthmatic, the polarization of their immune systems into an atopic phenotype probably occurs during early childhood. There is evidence that parental reports of life stress are associated with subsequent onset of wheezing in children between birth and one year. It has been speculated that stress triggers hormones in the early months of life which may influence Th2 cell predominance, perhaps through a direct influence of stress hormones on the production of cytokines that are thought to modulate the direction of immune cell differentiation.

Work by Hirsch (2003) can be interpreted as suggesting that obesity, which is also seriously epidemic in the USA, is a developmental disorder with roots in utero or early childhood. Hirsch and others have developed a 'set point' or homeostatic theory of body weight, finding that it is the process which determines that 'set point' which needs examination, rather than the homeostasis itself, which is now fairly well understood. Hirsch concludes that the truly relevant question is not why obese people fail treatment, it is how their level of fat storage became elevated, a matter, he concludes that it is probably rooted in infancy and childhood, when strong genetic determinants are shaping a still-plastic organism.

A lively debate rages regarding various possible subforms of psychopathy, a mental disorder characterized by a long history of manipulative, impulsive, and callous antisocial 'cheating' behavior. Mealey (1995) places the disorder in an evolutionary perspective as either a genetically determined or an acquired 'life history strategy' very similar to Nunney's (1999) analysis of cancer, albeit at the social rather than cellular level of interaction. Paris (1993) attempts to provide a comprehensive, integrative, biopsychosocial perturbed 'condition-development' model for personality disorders, while Lalumiere *et al.* (2001), by contrast, find evidence for a strict life-history strategy model, concluding, as a result of studies on children and adolescents, that 'If psychopathy is a result of condition-development, the environmental triggers are likely to operate very early'. The review by Herpertz and Sass (2000) examines the hypothesis that pathologically neglectful parenting and early social rejection contribute to onset of the disorder, particularly in the context of 'individualistic' social structures (e.g. Cooke, 1996). We speculate that it is possible to place the 'social cheating' of psychopathy in the same context as Nunney's cellular cheating for cancer, consequently being subject to the standard pattern of gene-environment 'norms of reaction' which will emerge as structured psychosocial stress has impact over the course of child development, probably beginning *in utero*.

Anxiety disorders have a long history of attribution to developmental factors and early childhood exposures (e.g. Bandelow *et al.*, 2002). More generally, Egle *et al.* (2002) find evidence that early biological and psychosocial stress in childhood is associated with long-term vulnerability to various mental and physical diseases. Research findings have, in their view, accumulated on those emotional, behavioral and psychobiological factors which are responsible for the mediation of lifelong consequences including increased risk of somatization and other mental disorders such as anxiety, depression and personality disorders. These often result in high-risk behaviors that are associated with physical disease: cardiovascular disorders, stroke, viral hepatitis, type 2 diabetes, chronic lung disease, as well as with aggressive behavior.

We are led to suggest that these case histories represent a far more general phenomenon in the etiology of the larger spectrum of chronic and comorbid mental and physical disorders, in the sense that structured psychosocial stress can literally write an image of itself upon the developing child, and if acute enough, on the adult, initiating trajectories to comorbid mental and chronic physical disorder.

For those dubious of Generalized Cognitive Homunculus regression model arguments, a brief reformulation in terms of the abstract development of Section 3 above may be of interest. Recall that the essential characteristic of cognition in our formalism involves a mapping, $h(x)$, of a (convolutional) path $x = a_0, a_1, \dots, a_n, \dots$ onto a member of one of two disjoint sets, B_0 or B_1 . Thus respectively either (1) $h(x) \in B_0$, implying no action taken, or (2), $h(x) \in B_1$, and some particular response is chosen from a large repertoire of possible responses. We discussed briefly the problem of defining these two disjoint sets, and suggested that some 'higher order cognitive module' might be needed to identify what constituted B_0 , the set of 'normal' states. Again, this is because there is no low energy mode for information systems. That is, virtually all states are more or less high energy, high information content or transmission, states. Thus there is no 'natural' way to identify a 'ground state' using the physicist's favorite variational or other minimization arguments.

Suppose that a higher order cognitive module, which we now recognize as a kind of Zero Mode Identification, interacts with an embedding language of structured psychosocial stress (or other systemic perturbation). Instantiating a Rate Distortion image of that embedding stress, the ZMI begins to include one or more members of the set B_1 into the set B_0 . Recurrent 'hits' on that aberrant state would be experienced as episodes of highly structured comorbid mind/body pathology.

Empirical tests of this hypothesis, however, quickly lead again into real-world regression models involving the interrelations of measurable biomarkers, beliefs, behaviors, reported feelings, and so on, requiring formalism much like that used in Section 5.

7. USING THE MODEL

Much of our reasoning has been based on a fairly elaborate mathematical model of cognitive process. Mathematical models of physiological, social, and other ecosystems - like those we present here - are notorious for their unreliability, instability, and oversimplification. As it is said, "all models are wrong, but some models are useful". The mathematical ecologist E.C. Pielou (1977, p. 106) finds the usefulness of models consists not in answering questions but in raising them.

This is a fundamental, and often poorly understood, matter. We are dubious of even successful attempts to 'fit' this, or any similar, broadly conceptual model to data. This is because, even if the model indeed fits certain circumstances, nothing really has been proved. As Pielou puts it (Pielou, 1977: 106):

"...[Mathematical models] are easy to devise; even though the assumptions of which they are constructed may be hard to justify, the magic phrase 'let us assume that...' overrides objections temporarily. One is then confronted with a much harder task: How is such a model to be tested? The correspondence between a model's predictions and observed events is sometimes gratifyingly close but this cannot be taken to imply the model's

simplifying assumptions are reasonable in the sense that neglected complications are indeed negligible in their effects...

In my opinion the usefulness of models is great... [however] it consists *not in answering questions but in raising them*. Models can be used to inspire new field investigations and these are the only source of new knowledge as opposed to new speculation.”

We have elsewhere made a detailed application of this theory to the US obesity epidemic, using the model to direct empirical exploration of the impacts of public policies causing massive population shift and economic displacement. Data suggest that, since the late 1980's, the resulting stress has apparently reset the bodymass set point of an increasingly large segment of the US population (Wallace and Wallace, 2003). Further, recent work on brain imaging and other exploration of consciousness appears suited to our approach in that these studies should be amenable to a search for tunable phase transition power laws and ‘generalized Onsager relations’ (Wallace, 2004).

Our conceptual model has particular implications for understanding the impacts of child poverty, especially in the US. According to a recent report by the National Center for Children in Poverty (NCCP, 2003), 57% of African American, 64% of Latino and 34% of white children suffered significant deprivation in 2001. These numbers are unprecedented for a Western industrial democracy. Our model suggests that full-scale empirical study will show this condition is a principal driving force, at the population level of analysis, behind an unexpectedly full spectrum of comorbid later-life psychiatric and chronic physical disorders in the US. Our model-based prediction, then, is a qualitative one, regarding the massive breadth of the developmental mind/body dysfunction which appears an inevitable consequence of maternal/childhood poverty in the US.

8. CONCLUSIONS

Our conclusion that a pattern of comorbid and anticomorbid mental and chronic physical disorder represents a pathological, ordinarily atypical or transient, state is consistent with theorizing in both autoimmune disease and mental disorder. Gilbert (2001), for example, uses an evolutionary approach to conclude that the relatively small number of evolved adaptive defence mechanisms, for example the flight-or-fight hypothalamic-pituitary-adrenal (HPA) axis, may become pathologically activated to produce mental disorder. He suggests that such evolved defences, of which there is a limited number, can become pathological when they are too easily aroused or prolonged, are arrested (i.e. aroused but not expressed), or are ineffective. These might involve depression, anxious arousal, or heightened vigilance to threat, with the type of defence (e.g. flight, fight, submit, help seeking) being mirrored in particular symptom presentations.

Jones and Blackshaw (2000) likewise argue that behavioral similarities between humans and animals show that many psychiatric states are distortions of evolved behavior, a perspective which provides, in their view, a new etiological approach to psychiatry transcending current mainstream empirical and phenomenological approaches which are principally forms of symptom classification.

Although individual pathologies of both mind and body may predominate in particular cases, our work here encompasses a broad spectrum of chronic diseases, emotional disorders, and classic cognitive dysfunction, in the context of the local sociocultural network so important in human biology. We further explore the particular effects of structured psychosocial stress in the development of comorbid mind/body symptom patterns over the life course.

We conclude that comorbidity may well be to medicine what punctuation in the fossil record has been to evolutionary theory (e.g. Gould, 2002) providing an opportunity for significant extension of our understanding and our ability to intervene against individual and population-level patterns of pathology.

The model which emerged focuses on the 'eigenstructure' of a generalized cognitive homunculus, and particularly on the failure of a higher cognitive module which permits identification of the 'zero mode' of such a homunculus. We conclude that, for certain classes of mind/body symptomatology, early experiences of exposure to structured psychosocial stress, particularly childhood poverty, can trigger identification of a highly atypical mode as the 'normal' zero-reference state. This will often initiate a life course of comorbid or anticomorbid psychiatric and physical disorders. The characteristic pattern we have in mind would involve individual and population-level comorbidity among obesity, asthma, diabetes, hypertension, depression, anxiety, substance abuse, ruthless or violent behaviors, coronary heart disease, certain cancers, and asthma or lupus; what might well be characterized as 'oppression disorder' at the individual level.

We conclude that historical patterns of discrimination, deprivation, and injustice are a determining feature in population-level expression of comorbid psychiatric and chronic physical disorder, patterns which are literally an image of that system imposed upon children, beginning in their mothers' wombs. To reiterate, our modeling exercise implies that maternal/child poverty is a principal determinant of an unexpectedly broad and characteristic life-course spectrum of population-level patterns of comorbid psychiatric and chronic physical disorder in the US. This is an empirically testable hypothesis.

The works of Memmi (e.g. 1969) and Fanon (e.g. 1966), however, show clearly that, for such systems as ours, the reflective nature of structured psychosocial stress ensures that the health and welfare of both dominant and dominated populations will be closely linked through a wide variety of mechanisms. We conclude that, while generalized developmental disorders may be concentrated in populations of color in the USA, they cannot be contained there, and will inevitably diffuse up the social hierarchy, entraining even affluent populations (e.g. Wallace and Wallace, 2003).

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