Towards a Functional Model of Mental Disorders incorporating the Laws of Thermodynamics

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ABSTRACT

The current paper presents the hypothesis that the understanding of mental disorders can be advanced by incorporating the laws of thermodynamics, specifically relating to energy conservation and energy transfer. These ideas, along with the introduction of the notion that *entropic activities* are symptomatic of inefficient energy transfer or disorder, were used to propose a model of understanding mental ill health as resulting from the interaction of entropy, capacity and work (environmental demands). The model was applied to Attention Deficit Hyperactivity Disorder, and was shown to be compatible with current thinking about this condition, as well as emerging models of mental disorders as complex networks. A key implication of the proposed model is that it argues that all mental disorders require a systemic functional approach, with the advantage that it offers a number of routes into the assessment, formulation and treatment for mental health problems.

INTRODUCTION

Mental health services currently work largely within a paradigm whereby mental disorders are generally understood as discrete diagnostic categories within a medical model of abnormality. Despite the acknowledgement that this model has a number of limitations, and attempts to address the shortcomings of diagnostic categorisation,[1,2] the limited recognition that humans are subject to universal laws results in a failure to conceptualise mental disorders in systemic and systematic ways. The aim of the present paper is to present a model of mental disorders as resulting from a failure of normal homeostatic processes.

Life and universal laws

By definition, all living organisms undertake three functions: the transfer of energy; growth; and reproduction. All life forms, including human beings exist by the transfer of energy and, as such, are subject to universal laws, such as the laws of thermodynamics.[3] The most relevant aspects of the laws of thermodynamics for our discussion state that, firstly, there exists a finite amount of energy which can only be transferred from one form to another, rather than changing in absolute quantity and secondly that the transfer of energy can never occur with complete efficiency. Energy which is not transferred into constructive work is referred to as *Entropy*.[4]

Human healthy functioning

Humans, as with all life forms, are subject to internal and environmental demands and changes which result internally in changes in substrate concentration, temperature and pH changes. The body self monitors and regulates in order to accommodate to these changes (see Kitano[5] for a discussion of homeostasis and

biological robustness). Homeostasis is, therefore, the maintenance of the self in a reasonably stable state in response to change.[6]

Health can, therefore, be conceptualised as the homeostatic state achieved when the amount of energy transferred efficiently is within the optimal functional capacity of the body's system required to meet the current environmental demands. This is captured in concepts such as adaptive behaviour, adaptive functioning, physical health and mental health, whereby health is conceptualised as a state of well-being, rather than an absence of illness (e.g. World Health Organisation[7]). Ill health, by contrast, can be considered to be a state which results from a lack of homeostasis in the system.

HYPOTHESIS

The present paper hypothesises that health and ill health can be conceptualised as follows:

$$\text{Health} = \frac{(\text{Energy} - \text{Entropy}) \times \text{Capacity}}{\text{Work}}$$

In this model *Energy* is defined as that which is required to do the *Work* i.e. meet the current internal and/or external environmental demands, (resulting in Order for the organism); *Capacity* represents the capability of a person to optimally function in relation to meeting current environmental demands. *Entropy* is the energy transferred into other uses and, therefore, not available to do the required *Work* (resulting in Disorder for the organism). It is hypothesised that this model will have particular utility in assessing and treating what are currently commonly conceptualised as distinct mental disorders.

EVALUATION OF THE HYPOTHESIS

In order to adequately test the model proposed above, it is necessary to be able to assess the components in a systematic way and also determine whether the model fits with the existing evidence base in respect of mental disorders.

Assessing the model components

A number of systems currently exist that allow us to measure aspects of capacity. These include intelligence tests, [8] measures of adaptive functioning (e.g. Harrison & Oakland[9]), personalty[10], central coherence, for example through the use of measures of executive functioning;[11] as well as specific assessments of behavioural functioning in a range of domains. Individual differences in factors that influence capacity, such as in emotion regulation[12] can also be assessed. This is not to deny the complexity involved in such measurements of capacity. If we consider intelligence, for example, in a little more detail, we see that many definitions make reference to capacity and the ability of the individual to function well within a given environment:[13]

‘ . . ability to adapt effectively to the environment, either by making a change in oneself or by changing the environment or finding a new one. . . intelligence is not a single mental process, but rather a combination of many mental processes directed toward effective adaptation to the environment.” Encyclopedia Britannica, 2006 (as cited by Legg & Hutter[13]).

Intelligence tests, however, cannot be considered to be discrete measures of capacity, often interacting with other aspects that influence capacity, such as personality[14] (See Borghans et al.[14] for example for a discussion of the relationship between intelligence, personality traits and achievement).

Other functional systemic models for understanding mental disorders exist, probably the most common of which is formulation. Formulation, as used by clinical psychologists, differs from that of psychiatrists in that it aims to draw on and integrate a range of intra and interpersonal, biological, systemic, social and cultural information

to explain the individual's difficulties in functional terms, rather than in terms of differential diagnoses.[15]

A number of behavioural systems, that are compatible with both formulation and the proposed model exist, that allow for the systematic exploration of the individual/environment interaction (*work*). One example is analogue assessment, a systematic behavioural observation system which records changes in target behaviours under simulated conditions which are designed as an analogue for natural circumstances, such as demands, attention and lack of stimulation.[16] Such behavioural systems are, however, perhaps best illustrated by the psychological concept of functional analysis (FA). FA is a system that is compatible with scientist practitioner models of human behaviour and is based on the following assumptions: behaviour is defined as anything a person does that can be observed; all behaviour occurs for a reason; systematic observation and evaluation of behaviour leads us to ways of understanding the functional relationships that occur between personal functioning, relationships with others and environmental demands.

FA has a number of benefits in terms of influencing system change: it feeds directly into the formulation process; it is the most effective way of assessing challenging behavior[17] which indicate system *Entropy* or *Disorder*; it is related to successful outcome, as measured by reduced challenging behaviour (e.g. Didden et al. [18]); interventions that are not based on FA and formulation, are likely to be ineffective and may cause challenging behaviour to increase;[19] it helps to ensure a 'goodness of fit' of the intervention with the values and characteristics of individuals, relevant to others and the environment.[20] As such it is reflected in professional practice guidelines.[19]

Through the application of the principles of FA, behaviour can be viewed as serving a homeostatic function whereby the human system strives to operate within optimum parameters in response to changes in, for example, levels of stimulation, attention or demand.

Summary of the proposed model

In summary, the present paper proposes that all human behaviour, including those which are considered to be symptoms of mental disorders, can be viewed as a means of achieving homeostasis. The mechanism by which this occurs is through balancing the environmental demands (work) with the energy and capacity of the person. The next section will outline the application of this model to a common developmental disorder: Attention Deficit Hyperactivity Disorder (ADHD).

Applying the model in practice: ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is categorised as a developmental disorder and diagnosis is based on the presence of inattention, hyperactivity and poor impulse control at a level that is developmentally inappropriate.[21] Recent estimates of the condition based on parent reported diagnosis in a United States representative sample of over 90,000 parents of children up to age 17 found a prevalence of 8.2%. [22] ADHD is co-morbid with a range of other diagnosed conditions including learning disability, anxiety, depression, and conduct disorder (see Larson et al.[22] for an overview). Pharmacology is often the treatment of choice for ADHD [23] with psychostimulants, such as Methylphenidate being most commonly prescribed based on the rationale that it influences the release and uptake of dopamine, which, in turn is associated with reinforcement and motivation.[24]

It is, however, increasingly being recognised that the diagnosis of ADHD covers a heterogeneous population, that differ in terms of the behavioural expression

of the diagnostic criteria, underlying neuropsychological difficulties and comorbid conditions and that there are multiple pathways that result in the disorder (see Wåhlstedt et al.[25] for an overview). Indeed, research by Wåhlstedt et al.[25] suggests that the symptoms of ADHD are associated with at least two pathways: regulation deficits in higher order cognitive mechanisms i.e. executive functioning; and difficulties with more 'bottom-up' mechanisms, such as state regulation i.e. the control of arousal levels, effort and activation.[26,27]

In the context of this research and applying the model proposed in the current paper, people with ADHD can firstly be considered to be experiencing ill *health* in that they have areas of poor adaptive functioning, commonly expressed as impairments in academic performance and social relationships,[22,28] and later antisocial and delinquent behaviour.[29] This ill health can be considered to result from a lack of homeostasis at various points in the system, as illustrated by the work of Wåhlstedt et al. [25]

In this context problems with *capacity* can be viewed as the range of neuropsychological and cognitive impairments demonstrated by children and adults with ADHD both through standardised neuropsychological testing and through measures of academic achievement at school.[30] These impairments in capacity are likely to interfere with efficient energy transfer, as limited capacity in areas such as cognitive attention, executive functioning,[31] and specifically poor behavioural and response inhibition[32] are expressed as fidgeting, inattention, distraction, shouting out and other behaviours that are seen as disruptive in classroom and other settings. Such behavioural symptoms of ADHD can, therefore, be conceptualised as *entropy* and this *entropy* is likely to increase in situations where environmental demands (*work*) result in over or under stimulation. This may be exhibited in practice in situations where the

child is unable to fully express their physical energy because the situation requires that he/she sits still and focuses or where the task at hand is too difficult, too easy, too stimulating or too dull for the child to be able to engage in it in a meaningful way. This lack of engagement can again be conceptualised as inefficient energy transfer and the child will engage in entropic activities as a means of trying to regain homeostasis.

The evidence that ADHD can be conceptualised as a heterogeneous condition[25] as well as that the comorbidity of many mental health conditions can best be understood by conceptualising them as comprising different nodes within a network model, which can be reached by multiple pathways[1] suggests a clear role for an approach such as FA in helping to determine the most influential factors for a given individual. For example, the behavioural symptoms that are used to categorise those with ADHD can be seen as resulting from common, but multiple routes of *entropy*, such as too much energy expressed as disruptive behaviour in environments where physical demands are low, physical expression constrained and state regulation and/or executive functioning is compromised. The fact that the combination of circumstances will vary from individual to individual in terms of *capacity*, *energy* and *work*, means that a systems level approach, such as FA is required in order to adequately understand the function of the behaviour and devise appropriate interventions that target the sources of *entropy*.

CONSEQUENCES OF THE HYPOTHESIS

Implications for assessment and treatment

The proposed model could be specifically utilised by practitioners working in mental health services as it offers a framework by which mental disorders could be conceptualised and assessed in a functional multi-disciplinary way, leading to a range

of potential routes for intervention. The proposed model, while compatible with the current model of psychological formulation, differs in some important respects. The latter framework is a cornerstone of psychological assessment and evaluation[15] and can be used to conceptualise the behaviours that are viewed collectively as representing the developmental disorder ADHD. While the approaches that are applied within the formulation framework are underpinned by psychological theory, the formulation model is, in itself, essentially a-theoretical. By contrast, the model proposed in the present paper is theory driven and derives from universal laws, specifically the laws of thermodynamics. A key implication of the proposed model is that it argues that all mental disorders require a systemic functional approach, with the advantage that it offers a number of routes into the assessment, formulation and treatment for mental health problems. This may be somewhat at odds for many categorical diagnostic approaches which propose the assessment and treatment of unitary disorders using single lines of treatment.

Treatment under the proposed model would comprise of interventions aimed at maximising homeostatic functioning. Interventions can, therefore be seen as a range of means of *entropy management*. Psychopharmacology, in this model, can be viewed broadly as a means of energy management, by influencing the nature of energy transfer at the synapse.

Using the example of ADHD, effective interventions for the symptoms of ADHD, as with other forms of challenging behaviour, are likely to comprise multi-modal approaches, comprising ecological strategies i.e. changing the environment the behaviour occurs in, behavioural approaches which target the specific behaviours that are considered to be problematic by changing the behavioural contingencies, pro-active strategies which offer the individual alternative means to achieve the function

that the behaviour serves and/or address specific individual needs.[19] A recent evaluation of a multimodal intervention for children with ADHD found, for example, that it resulted in substantial and lasting improvements in neuropsychological functioning, compared with a control group.[33]

The need for multimodal approaches and that pharmacology represents only one strand of such multimodal treatment is already recognised within the National Institute for Health and Clinical Excellence (NICE) guidance on ADHD [34]. This emphasises the importance of comprehensive assessment and behavioural/cognitive behavioural approaches and specifies that 'Drug treatment for children and young people with ADHD should always form part of a comprehensive treatment plan that includes psychological, behavioural and educational advice and interventions' (p 11). There is also a growing evidence base that psychological and behavioural approaches based on FA can be effective in managing symptoms of ADHD in adults.[35]

Conclusion

The present paper hypothesises that by incorporating the laws of thermodynamics, the understanding of mental disorders can be progressed. These ideas, along with the notion that *entropic activities* are symptomatic of inefficient energy transfer or *disorder*, were used to propose a model of understanding mental ill health as resulting from the interaction of entropy, capacity and work (environmental demands). The model was applied, using the developmental disorder ADHD as an example, and was shown to be compatible with current thinking about the disorder as well as emerging models of mental disorders as complex networks. Future research, which explores the extent to which the proposed model provides a 'fit' for other mental disorders, will help determine the utility and generalisability of it.

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