A Proposal for a Model of a Mental Health System

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Abstract

Both Psychatric breakdown and recovery involve the way in which the stresses and stimulations of the psycho-social environment of people impact upon aspects of their personhood and brain-functioning. The treating of these matters entails the development and application of therapies to people within a range of connected 'stress-stimulation' environments that, when taken together, might be described as a mental health system.

This paper begins with a proposal for a systemic model for such a system, and continues with an attempt to quantify it as a semi-markov process. In the simplest case in which the times in the respective states are described by Geometric Distributions, the whole process is Markov. For this case we derive the following recurrence relation for the Probability Generating Function of the numbers in the various environments:

$$G_t(z) = G_{t-1}(u(z)), \text{ where } u_j(z) = \frac{z_j}{(\pi_j z_j + 1 - \pi_j)} \prod_{k=1}^{n} (\pi_j \, p_{jk} \, z_k + 1 - \pi_j \, p_{jk})$$

Using this we can find explicit expressions for the mean numbers in the particular environments under stationary conditions.

$$\mu_j = N \frac{t_j}{\pi_j} \bigg/ (\sum_{k=1}^{n} \frac{t_k}{\pi_k}), \text{ where } t \text{ is any solution to } t = tP \quad,$$

The paper concludes with a look at the way in which a simulation version of the general semi-markov model might be able to be used as a decision-making tool in the field of Mental Health.

1. Introduction

Psychiatric breakdown is a complex process involving the relationship between the internal brain functioning of people, the stresses imposed upon them by their external environment and the psychological abilities of people to manage and cope with both of these things simultaneously.

Medical science focuses upon issues arising from the pathology of the processes and structure of the physical and biochemical systems taking place within the human body. In this respect, whilst Neuroscience has made great strides in recent years, when it comes to the abnormalities associated with serious psychiatric disorders such as bipolar disorder and schizophrenia, there is still a very

long way to go before the causes of the pathology may be said to be understood. In this respect, Psychiatry may be said to be a clinically orientated medical discipline that, at least in modern times, is based upon the assumption that such disorders arise because of a combination of abnormalities in the structural and physiological processes of the brain. Under such assumptions, the principal means of clinical treatment arises from the administration of drug treatments. A whole range of antipsychotic, antidepressive and other forms of "brain-functioning medications" have been developed in the last fifty years. In most cases the administration of these drugs does not "cure" the disorder. Rather, it appears to be able to "check" some of the physical/biochemical process abnormalities related to the functioning of the brain, where these are associated with mood, feelings and thoughts. One of the problems with such treatment is that the administration of such medication often "checks" both pathological and normal brain function, producing unwanted side-effects, thus often making clinical psychiatry a delicate balancing act.

In this sense, it may be said that the principal concern of psychiatry is with those aspects of the mental or brain functioning of people over which they have little or no conscious control - they are associated with the physical and biotic levels of bodily function, albeit in close relationship to the feeling, perceptual and thought levels that are typify the internal life of human beings. Clinical psychology, on the other hand, typically focuses upon the specific levels of this internal life of feelings, emotions and thoughts over which the person concerned does have a measure of control. In the case of serious psychiatric illness, however, these two aspects - the pathology of brain function and personal awareness of the strange perceptions, feelings, moods, thoughts and cognitions that are symptomatic of the condition - can make for serious problems in gaining some effective control.

In addition to the systemic functioning of the physical and biotic substructures of the human body, and their complex relation to the subjective functioning of feelings, mood and thoughts of people, the role played by various environments (social, cultural, aesthetic, natural, work etc) in respect of healthy mental functioning, is significant. Thus, the mental health of a person has a physical and biotic substructure and a social/cultural/geographical superstructure. In between it involves a subjective structure of feelings, perceptions, mood and thoughts that are observable to others both by means of actions and behaviour as well as by the signs and symbols made by them.

Generally speaking, mental breakdown occurs in a situation in which the stresses caused by the external environment, or superstructure, are such as to cause some kind of overload to the internal brain processes of the physical/biotic substructure, resulting in its serious impairment. This is accompanied by serious effects upon the psychological functioning of the person concerned. They can become traumatised, depressed, disoriented; they can lose confidence, motivation, lose hope and lose the skills they once had.

We may describe the process of recovery and rehabilitation as the mending and rebuilding of these brain processes in ways that are accompanied by a strengthening of the psychological injury to self-esteem, confidence, motivation and initiative. In this respect, the activities and social interaction imposed by the stress level of the environment can play just as important a role in the recovery/rehabilitation process as it does in the breakdown.

Rehabilitation is concerned with a great deal more than health issues. It concerns a whole range of personal and professional skills that may have been impaired by breakdown. Moreover, even though a person's interpersonal and professional skills may be restored to proficiency, a range of problems relating to their ongoing psychiatric condition may still make it very difficult for them to obtain employment and enjoy the other benefits of life in mainstream environments.

In this sense we may say that the process of recovery and rehabilitation may be facilitated by creating a range of environments - from *protected* through *sheltered* to *open* - in which the level of environmental stress one experiences when engaging in a range of necessary activities may be shaped in such a way as to actually strengthen self-esteem and confidence, as well as develop skill levels. That is, stressors may actually assist the person gain a sufficient level of control and confidence to be able to live effectively in mainstream (or "open") environments.

In the first place, System Analysis can assist us to understand the way in which these stress-stimulation environments interact. In the second, we may appreciate the aim of both health policy, clinical treatment and other support services to be that of endeavouriing to improve the ways in which people are able to move from one such environment to another.

Finally, by means of an attempt to quantify the model as a Stochastic Process – introducing probablities of movements of people between environments, and probability distributions of lengths of stay within each such environment – we can model the Health System as a semi-markov process

2.   A Simple Systemic Model of a Mental Health System

With reference to what might be described as stress/stimulation environments in any mental health system, we might analyse it as involving at least the following four types of environmental settings:

Protected Environment - comprising hospitals. These may vary in terms of the treatment, care and freedom allowed to the patients whilst in care. They may also vary in the standards of the facilities as well as other matters.

Limited Environment – comprising people who 'live in the community', but are severely limited in their contact with it. They have no job, little or no interaction with educational institutions or clubs. They are supported and maintained principally by Community Health officials and family /friends.

Sheltered Environment – comprising people who not only 'live in the community' but also participate in Government and/or other rehabilitation services in ways that seek to improve both their self-esteem and confidence in ways that (a) enable consumers to have a more rewarding social and recreational life and (b) enable some to be able to move on to effective employment as well as other features of the open environment. The main examples of these kinds of environments within New South Wales have been provided by Living Skills Centres and Clubhouses. The former of these are being phased out ,and replaced by a variety of non-government agencies designed to achieve similar objectives.

Open1 Environment – comprising people who live in the community, have a job and interact effectively with a variety of clubs / educational institutions etc. and have no history of mental illness and no contact with the mental health system.

Open2 Environment – comprising people who live in the community, have a job and interact effectively with a variety of clubs / educational institutions etc. and have a history of mental illness and continue to have contact with the mental health system.

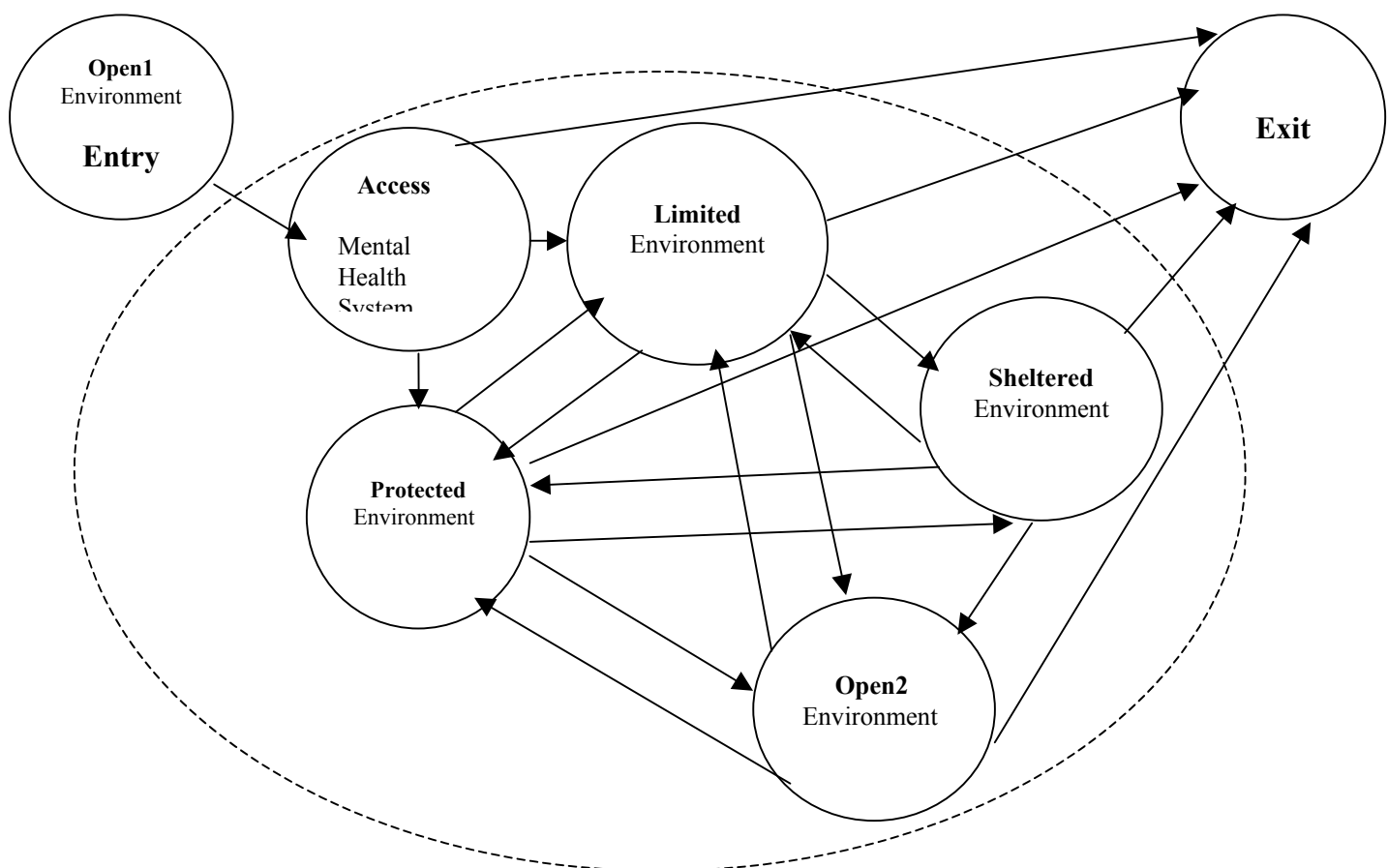**Exit Environment** – those who have at one time had contact with the mental health system, but

have since permanently left the system. For the purposes of the model, we assume that they rejoin the Open1 Environment.

Access – preliminary contact with the Mental Health System, from which clients are referred to other parts of service, including exit.

It is possible to envisage other types of environmental settings. In particular, whilst the 'Sheltered Environment' as described above may be thought as one that provides 'permanant disability support' for those affected by mental illness, it is possible to envisage an environmental setting with the objectives of a 'Bridging Environment' in which that assists people to develop and rehabilitate the necessary psycho-social skills that will better enable them to move into the Open1 Environment, as described above. It is obvious that the maintenance of all the above environments, with the exception of the Open1 and Exit environments involves costs to the public purse. However it is not our purpose at this stage of the modelling process to examine and include these costs.

A Quantitative Model Based on the Above.

The immediate objective is to model both the lengths of stay and the probability of movement at the end of such a stay from one of these environments to another. This can be done with the following version of the four stress/stimulation environments mentioned above.

Upon a daily basis it should be possible, using appropriate data, to estimate the following probabilities of daily movements from one such environment to another:

From the Open1 Environment
- Probabilities of the numbers entering the system per day. All go directly to Access.

From Access

- The probability of a person entering the Protected Environment from Access.
- The probability of a person entering the Limited Environment from Access.
- The probability of a person exiting the system (being referred elsewhere).

From the Open2 Environment (at end of stay)

- The probability of a person entering the Protected Environment from the Open2 Environment.
- The probability of withdrawing from the Open2 Environment into the Limited Environment.
- The probability of exiting the system.

From the Protected Environment(at end of stay)

- The probability of a person leaving the Protected Environment for the Limited Environment, without entering into the Open2 Environment in the sense discussed above.
- The probability of entering the Open2 Environment from the Protected Environment.
- The probability of entering the Sheltered Environment from the Protected Environment.
- The probability of exiting the system.

From the Limited Environment(at end of stay)

- The probability of a person needing to enter the Protected Environment from the Limited Environment.
- The probability of entering the Open2 Environment from the Limited Environment, however still considered part of the system through contact with case managers etc.
- The probability of entering the Sheltered Environment from the Limited Environment
- The probability of exiting the system.

From the Sheltered Environment(at end of stay)

- The probability of a person needing to enter the Protected Environment from the Sheltered Environment.
- The probability of entering the Open2 Environment from the Sheltered Environment, however still considered part of the system through contact with case managers etc.
- The probability of entering the Limited Environment from the Sheltered Environment.
- The probability of exiting the system.

This model of the system comprising the seven environment states (two environments outside the mental health system; five within it) mentioned assumes a common probability distribution of the length of stay in each environment, independent of how the client entered the environment. A further assumption will be made to the effect that *Open1* and the *Exit* comprise the same state.

3. A Semi-Markov Stochastic Process Model of a Mental Health System.

In general terms we may abstract the appropriate numerical features of our systemic model to define our quantitative model as follows:

We have n states in our system (not all of which, in the strict sense, are stress/stimulation environments).

T_j = Random Variable describing the length of stay in State j ($j = 1...n$)

p_{ij} = Probability of an individual moving to State j after concluding a stay in State i

$N_j(t)$ = Number in State j on day t

$M_j(t)$ = Number leaving State j on day $t-1$ going to another State on day t

$Q_{ij}(t)$ = Number coming into State j on day t leaving State i on day $t-1$

Then $M_k(t) = \sum_j Q_{kj}(t)$. By considering all the ins and outs from State j on day $t-1$ we have

$$N_j(t) = N_j(t-1) - M_j(t) + \sum_{i=1}^{n} Q_{ij}(t) \qquad \text{**}$$

In the general case the entire history of each T_j will influence both $M_j(t)$ and $Q_{ij}(t)$. Thus we have a semi−markov model for the system. Whilst its general mathematical analysis is possible it is somewhat intractable to the production of simple results.

However, if we make the assumption that each of the T_j follow geometric distributions, then we retain the main structural features of the model, but in a way that is still markovian. We can then obtain some very useful results.

4. The Case of Geometric Distributions for *T*

In this case we have   Prob $(T_j = k) = (1-\pi_j)^{k-1}\pi_j$ (k=1,2,3.......),
where π_j is the probablity of any person leaving state j on any day.

We then have the following results

$$E[z_j^{M_j(t)} \mid N_j(t-1)] = (\pi_j z_j + 1 - \pi_j)^{N_j(t-1)}$$

$$E[z_j^{Q_{ij}(t)} \mid N_i(t-1)] = (\pi_i p_{ij} z_j + 1 - \pi_i p_{ij})^{N_i(t-1)}$$

and therefore $E[\prod_{i=1}^{n} z_j^{Q_{ij}(t)} | N_1(t-1),....,N_n(t-1)] = \prod_{i=1}^{n} (\pi_i \, p_{ij} \, z_j + 1 - \pi_i \, p_{ij})^{N_i(t-1)})$

Using **, we have the following result for the Probability Generating Function,

$$G_t(z_1,......,z_n) = E[\prod_{i=1}^{n} z_i^{N_i(t)}]$$

$$E[\prod_{j=1}^{n} z_j^{N_j(t)} | N_1(t-1),....,N_n(t-1)] = E[\prod_{j=1}^{n} (z_j^{N_j(t-1) - M_j(t) + \sum_i Q_{ij}(t)} | N_1(t-1,....N_n(t-1)]$$

Hence,

$$G_t(z_1,....z_n) = E[\prod_{j=1}^{n} z_j^{N_j(t-1))} (\pi_j z_j + 1 - \pi_j)^{-N_j(t-1)} \prod_{i=1}^{n} (\pi_i \, p_{ij} \, z_j + 1 - \pi_i \, p_{ij})^{N_i(t-1)}]$$

$$= E[\prod_{j=1}^{n} (\frac{z_j}{\pi_j z_j + 1 - \pi_j})^{N_j(t-1))} \prod_{k=1}^{n} (\pi_j \, p_{jk} \, z_k + 1 - \pi_j \, p_{jk})^{Nj(t-1)}]$$

$$= G_{t-1}(u(z)), \quad \text{where}$$

$$u_j = \frac{z_j}{\pi_j \, z_j + 1 - \pi_j} \prod_{k=1}^{n} (\pi_j \, p_{jk} z_k + 1 - \pi_j \, p_{jk})$$

From this result (or alternatively from ** above), we obtain the following equation for the mean numbers in the various environments.

$$\mu_j(t) = \mu_j(t-1) - \pi_j \, \mu_j(t-1) + \sum_{k=1}^{n} \mu_k(t-1) \, \pi_k \, p_{kj} \qquad \forall \, j = 1,...,n$$

Under stationary conditions, this yields

$$\pi_j \, \mu_j = \sum_{k=1}^{n} \pi_k \, \mu_k \, p_{kj} \qquad \forall \, j = 1,....,n$$

If we then write $t_j = \pi_j \, \mu_j$ then the vector t corresponds with the steady - state vector of the Markov Chain with transition matrix $P = \{p_{kj}\}$. t therefore satisfies $t = tP$

Hence, if the constant size of the population is N, then we have the following :

$$\sum_{j=1}^{n} \mu_j = \sum_{j=1}^{n} t_j / \pi_j = N, \text{ whence } \mu_j = N \frac{t_j}{\pi_j} / (\sum_{k=1}^{n} \frac{t_k}{\pi_k})$$

5. A Simulation Model.

If the following data is available for a period of years:

1. The Number of people entering the Mental Health System via *Access* so as to identify the numbers entering the system for the first time on a daily basis.
2. The proportions of clients from *Access* going to the *Limited, Protected and Sheltered* parts of the system.
3. Data concerning the frequencies of the durations of stay within each environment, enabling the determination of the Probability Distributions of Lengths of Stay in each of the following environmental settings:

   - Open2
   - Limited
   - Protected
   - Sheltered

4. The relative frequencies of the movements to the other types of environments, when leaving a given environmental setting. This would enable the probabilities of going to alternate environments consequent on leaving one such environment, to be determined.

then the relevant parameters of the system can be estimated. Together with an appropriate simulation computer program, this would first of all enable the model to be tested – simply by comparing the statistics of the outputs of the simulation with those of the actual data from the system.

6. The Possible Use of the Simulation Model.

The probabilities of moving from one of these four stress/stimulation environments to another are dependent upon a whole range of factors, including:

- Effective early intervention programs leading to effective treatment.
- A knowledgable Public that is able to assist with early intervention programs.
- Effective drug therapies
- Effective Clinical Rehabilitation therapies
- Effective support and motivational programs

What are the likely effects of these changes upon the large scale distribution of those disabled by psychiatric illness in respect to the protected, limited, sheltered and open environments?

The model may be developed so as to assess the way in which the changes introduced to the system - estimated in terms of the parameters of the system – affect the means and other distributional features of the of the numbers in the various environments. This should be able to assist in the more effective management of the resources of care as well as the allocation of funds associated with it.

Once the model has been adequately tested, it could lead to the following further developments:

(i)   Predictions of possible consequences of policy changes affecting lengths of stay an movements between stress/stimulation environments. This would give esti-mates concerning the statistical properties of the numbers in the various environ-ments.

(ii) Extensions so as to be applicable (a) to other Area Health Services ;(b) to the inclusion of non-government organizations within a given Area Health Service into the model; (c) to include state-wide data so that it becomes a State-wide model.

(iii) The incorporation of economic factors into the model. This would be based upon the costs associated with maintaining the personnel and infrastructure appropriate for sustaining the communal resources for the numbers of people involved.

(iv) Modifying/adding to the types of environmental settings envisaged, including the possibility of experimenting with the kind of 'Bridging Environment' mentioned in Section 2.

(v) The development of a more complex model that would take the diagnostic categories of people into account.

7. The Development of the Model in Wentworth Area Health, New South Wales.

The system 'on the ground' in Wentworth Area, Western Sydney, NSW, comprises a range of both Government and Non-Government agencies. In terms of the analysis of the earlier part of the paper, some of these agencies are responsible for the shaping of environmental settings. Others simply contribute to the effectiveness of the transitions from one environmental setting to another:

Pialla Psychiatric Unit, Nepean Hospital (Government), Penrith - principal Protected Environment

St John of God Hospital, (nonGovernment), Richmond – Protected Environment

Child and Adolescent Mental Health Unit, Nepean Hospital – agency facilititating movement from limited, sheltered and protected environments to open2 environments.

Community Mental Health Centre, Wentworth Area Health service (Government) – agency monitoring people in various stress-stimulation environments, encouraging people to move from limited to sheltered or Open2 environments.

Westworks – a nonGovernment agency that seeks to provide employment for people with psychiatric disability. In this respect it is run as a business, with a management committee comprising a range of people – from the Director of the Penrith Chamber of Commerce to a range of consumers and health workers. As such it creates an Open2 environment that seeks to function as something of a bridge to open employment.

Westclub. – a nonGovernment agency, linked organizationally under Westworks, that seeks to create a sheltered environment facilitating social, recreational and educational activities that encourage people to move on to the Open2 environment, possibly through Westworks.

Active Employment – a nonGovernment agency that seeks to assist people recovering from Psychiatric breakdown to find employment on the 'open market'. In terms of the model, this is an agency that assists the movement of people from a 'limited' or 'sheltered' environment to an Open2 environment.

At this stage of the project, we are endeavouring to get the kind of data needed to develop the kind of Quantitative simulation model put forward in the paper. Suffice to say that it is not proving easy!