Professor Sandro Galea

Professor and Chair of Epidemiology, Columbia University

Thinking in systems, looking for the causes of population health

Overview

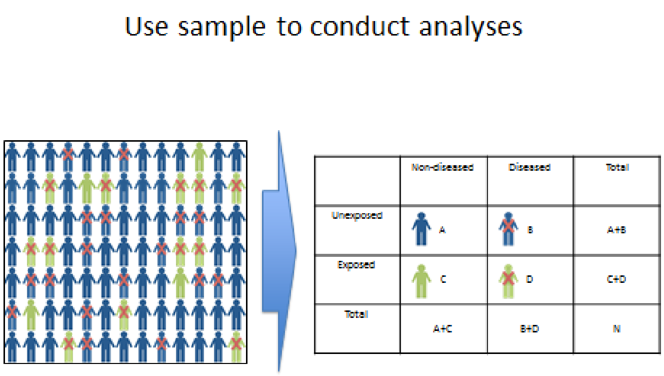
In this lecture Professor Galea outlined some of the strengths and limitations of current population health science and epidemiology.

He went on to describe the principles and benefits of thinking in a systems way as a means of addressing the shortcomings.

Finally he introduced the idea of system modelling and illustrated its use in the investigation of the relationship between social capital and violence. The nature of the systems model approach allowed new dynamics between these variables and others to be identified for the first time. He concluded that dynamic models point to different possible explanations for observed complex phenomena and that their use, in conjunction with empirical data, can help to narrow down possible explanations. He advocated that they should have a central role in public health analyses.

Population Health and epidemiology

Professor Galea began by suggesting that while the phrase population health is widely used; most people working on it are more interested in disease. He then outlined the basic epidemiology model in which in any given population some of those, but not all of those, exposed to known risks for a disease, alongside some of those not exposed, will contract it. Because the whole population cannot usually be studied, a sample is studied, and the choosing of a sample brings its own challenges. The analysis is conducted on the categories diseased/non-diseased, exposed/not exposed to risk as shown in the familiar two by two table shown on the right.



He highlighted the core underlying assumptions of this epidemiological simple system paradigm as:

- Homogeneous, interchangeable agents – one person is the same as any other person except for the variable controlled for in the analysis
- No change over time
- No structure, the location of any person in the system is largely immaterial
- No feedback among variables, but a deterministic, linear relationship among the variables under study

This model has been well used as it has been very successful in public health action – for example in smoking following the discovery of the link between smoking and cancer.
He used the often cited example of Jon Snow's discovery during a cholera epidemic that it was a water borne, and not an air borne disease as had been previously thought. A key point in the story is Snow's removal of the handle from the Broad street pump so that people could no longer draw water from it. This story is often represented as an important moment in the history of public health and its telling used to illustrate the power of a public health approach since the epidemic subsided after the handle was removed.

However Professor Galea showed a graph which illustrated that the epidemic was well into decline by the time the handle was removed and that its removal had no discernible impact on the decline. He suggested this was a caution against over confidence in the assumptions underlying the approach described above. There is, he said, a longer list of failures than successes based on this model. He underlined this critique by use of the cartoon on the right on the seemingly random nature of cause and effect. He suggested that while the model is helpful in simple situations, more often the phenomena under study are complex and in such contexts, a reductionist paradigm is not really helpful as it misses important elements of complexity. This makes it inadequate for our purposes.

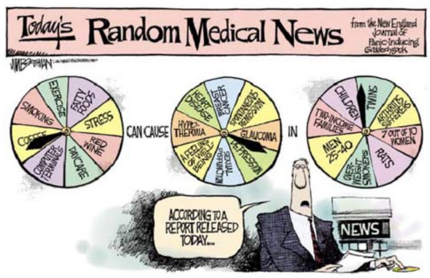


Figure 3: New England Journal of Panic-Inducing Gobbledygook.
Source: Jim Borgman, The Cincinnati Enquirer (27 April 1997, E4).

What is a complex system?
He began to answer the question 'what might be adequate?' by suggesting that it is an inherent part of the scientific process to simplify. He suggested that most inferential mistakes arise from oversimplification. Following Einstein he suggested that everything should be made as simple as possible but no simpler. A rose he said is a complex system, its properties emerging out of the complex interaction of its elements. He contrasted this with a simple array of linear dots on the one hand and a random pattern of dots on the other.
He listed the key characteristics of a complex system as:

- Heterogeneity, i.e. diversity of agents
- Nonlinear dynamics
- Contact structure, networks, organisation
- Feedback, adaptation, learning, evolution
- Stochastic with concern for tails
- Emergence
- Often no equilibrium

This, he said, began to reflect more fully the world at large. He gave herd immunity to disease as a good example of a complex process, i.e. if enough people are immunised against a disease an emergent property of the system is immunity to that disease. To study only the individual would miss this emergent property of herd immunity.

He went on to suggest that problems which do not yield to policy intervention are almost always complex system problems. For example, there are multiple interactions between people, significant feedback and interaction with the environment, nonlinearity between associations. Both history and trade-offs between desirable outcomes are often involved and outcomes can be counter intuitive with cause and effect often separated by both time and space. He illustrated this by citing the systems model of the UK foresight group on obesity which has a large number of interconnected relationships among variables. He concluded this part of his talk by reminding us of E. O. Wilson's idea that "the greatest challenge today…in all of science, is the accurate and complete description of complex systems". Professor Galea said that in his view, Public Health is behind many other disciplines in adopting systems thinking in its work.

Thinking in Systems
Drawing on work which he and his colleagues had recently completed, he illustrated the idea of systems thinking with references to causes of death in the USA in a way which helps to reconceptualise what these are.

He began by showing a familiar list of the diseases from which people died in the USA during the 1990's – heart disease, cancers, stroke etc. He then showed work by McGinnis and Foege which translated these diseases into their underlying causes. The list then looks quite different: tobacco, poor diet, physical inactivity, alcohol consumption etc. Although they defined the 'actual' causes of death as major external (non-genetic) factors contributing to death, these are primarily individual-level risk factors and behaviours.

Professor Galea and his colleagues took this one step further and asked how does the social environment fit into this system. How do these diseases and their associated behaviours 'get under the skin'?

They hypothesised that if it is possible to shift perspective from the disease to the behaviour associated with the disease, it ought to be possible to further shift the frame from behaviour to the impact of social factors on behaviour. Following the same methodology for six social factors shown in the table on the left, they found that:

- low education explained as many deaths as heart attack,
- low social support as many as stroke,
- racial segregation as many as lung cancer,
- income inequality as many as chronic respiratory disease,
- poverty as many as accidental injury, and
- area-level poverty as many as kidney failure.

Comparing deaths from social factors to other causes

Social Factor	No. (%)	Cause of Death	No. (%)
Low education	193 626 (8.3)	Acute MI	192 898 (8.0)
Low social support	179 937 (7.7)	Stroke	167 661 (7.0)
Racial segregation	153 796 (6.6)	Lung cancer	155 521 (6.5)
Income inequality	145 388 (6.2)	Chronic lower resp. dis.	122 009 (5.1)
Poverty	102 672 (4.4)	Unintentional injuries	97 900 (4.1)
Area-level poverty	39 553 (1.7)	Renal failure	36 471 (1.5)

Minino et al. Deaths: Final data for 2000. Natl Vital Stat Rep. 2002; 50: 1-120.

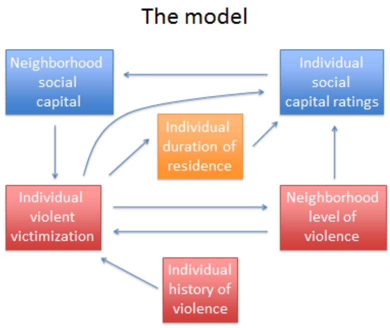
Overall they found that about 35% of deaths were attributable to social factors. In concluding this part of his lecture, Professor Galea highlighted that the six factors mentioned were simply foundation factors in a much wider system of interaction, association and causation. This system includes policy making outside of the health system narrowly defined and a remaining challenge is how to embed this as an integral part of policy making systems.

Modeling in Systems
Following the above example of the effect of thinking in systems on understanding causes of death and their policy implications, Professor Galea turned his attention to modeling in systems.

He began by talking about the appeal of social capital as a public health concept, particularly in relation to violence reduction. USA data suggest that at a State level as social capital increases, violence reduces. A difficulty is that most of these data are simply observational and associational and the effect of social capital on violence reduction has simply been accepted at face value. This has found its way into policy making circles and significant interventions have been funded based on this idea.

The data could equally be interpreted to suggest that violence reduces social capital. Which is more correct?

Citing a paper which he and colleagues published ten years ago, from which his team had subsequently developed methods for handling complexity, he illustrated that the relationship between social capital and violence is reciprocal. The team used agent based modeling by which individuals can make context influenced decisions which then feedback into the social system in a cyclical manner as shown on the right.



Using state level data from social surveys over 20 years their paper showed examples of movement in neighbourhoods from high social capital/high violence to high social capital/low violence and low social capital/low violence to low social capital/high violence (suggesting social capital reduces violence AND the opposite i.e. changes in violence lead to opposite changes in social capital). The data suggest this latter effect is stronger than the former i.e. changes in levels of violence have a stronger effect on social capital than the other way around.

Having established this, the study then developed a systems approach which tracked mobility and negative experience of violence by individuals. This showed that experience of violence caused people to move residence where they could. Thus the experience of violence, followed by victim mobility reduced social capital in the original neigbourhood. The research team identified two main challenges in this approach. Firstly, it was still unidirectional in its approach to causation and did not therefore have a strong enough reciprocal relationship between the variables in the system. As a result, it might not account for the critical drivers which are the hallmarks of complexity. Secondly, the assumptions in the model are still searching for an independent variable. So while the work could describe behaviour based on the data, the system or model could not be manipulated to further illustrate connections between the variables.

To address this, the team used data from New York on social capital and homicide, income etc to populate the model and began to both describe and anticipate connections in a complex system. This allowed the team to note the link between social capital and violence in a static way. There are as yet no dynamic relationships.

The team then ran longitudinal data to observe and anticipate links. This showed that cumulative experience of violence together with social and economic characteristics of a neighbourhood were associated with variations in social capital. As people move around, the characteristics of the neigbourhoods change. Thus it is possible to see the **underlying** properties of the relationship between social capital and violence. Those who can, move to a lower violence place. Over the years as this happens spatial clustering emerges around income and advantage.

This approach shows that a person's rating of social capital decreases if they are the victim of violence or if the level of neighbourhood violence increases by 1%. A person's rating of social capital increases for every five years they stay in an area or if neighbourhood violence decreases by 1%.

Linking this back to the original paper and using three models results in the following:
Model 1 assumes no person moves as a result of violence. Social capital decreases as violence increases (like a cross sectional analysis which is unable to describe the dynamic between the variables over time).
Model 2 persons can move in relation to violence. As mobility is added more people are exposed to violence (as the poor segregate into violent neighbourhoods). In this model, social capital seems to decline on its own, linked to duration of residence.
Model 3 is designed to more fully reflect mobility. This shows that violence drives social capital more than the other way around. The key discovery from this new approach is to see that violence drives residential mobility, which drives a decrease in social capital. This would not have been possible using a simple deterministic or complex static approach.

In conclusion Professor Galea suggested that the key ideas in his lecture were that:
- Dynamic models point to different possible explanations for observed complex phenomena
- Dynamic models can be used in conjunction with empiric data to narrow down possible explanations and should have a central role in public health analyses.