Simulating Dynamic Systems in Health Psychology

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Abstract

Despite their advocacy of the biopsychosocial model, health psychologists use a relatively narrow repertoire of techniques for developing and testing theory. These techniques have limited application to research questions concerning phenomena that are multidimensional, multilevel and change over time. This thesis demonstrates an alternative, dynamic systems approach to such questions in health psychology. It introduces some ideas in systems and dynamics and how we might model these. It uses an example to demonstrate the use of these ideas to develop a dynamic systems model in a health psychology context. The example is drawn from the epidemiological finding of a positive correlation between income inequality and mortality, and the proposal that this relationship may be mediated by processes that result in social disruption. The thesis explores the construction of a dynamic systems model to examine how a change in income inequality might affect the network of social relationships in a population. Social relationship processes in the model are based on some findings from social psychology, and these are incorporated into a network model, which is realised as a computer simulation.

Simulation runs suggested that an increase in income inequality can produce a ripple of relationship breakdowns. Contrary to intuition, the number of relationships lost was limited if the change was introduced suddenly, and if there was a high rate of making and breaking relationships. Further, reversing the change did not reverse the loss of relationships. The development process and the results obtained are discussed, and it is argued that dynamic systems simulation may be useful for developing and testing theory that applies to multilevel, multidimensional processes in health psychology.

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Introduction

Health psychology, by its very nature, tackles complex problems in which psychological, social and biological factors interact. The discipline's dominant model, the biopsychosocial model, explicitly recognises this complexity, suggesting that we should consider interactions along biological, psychological and social dimensions (Sarafino, 1998). Other factors also add complexity in health psychology. For example, we are interested in phenomena over a range of degrees of aggregation. Topics in health psychology can range from how individuals perceive and cope with illness, to the influences on the health of social groups, to the design and assessment of health promotion activities targeted at whole populations. Where the topic touches these higher degrees of aggregation, we cannot simply add individual behaviours together to explain the behaviour of a population.

Another source of complexity lies in understanding the dynamics of phenomena. These determine how individuals or populations respond to change, and how long term processes unfold. While we usually investigate static relationships, what we are often really interested are the effects of change. For example, we may be interested in what effect an intervention might have or what effect a change in the environment might have. To understand responses to change we need to understand the underlying processes, and to recognise an element of dynamics in health psychology.

Complex interactions of a number of individuals are characteristic of systems problems, as are questions of the dynamic response to change. Psychologists have long recognised that systems can be important in determining behaviour. But despite acknowledging likely systems effects, in health psychology we rarely incorporate explicit systems ideas into theories. The biopsychosocial model is a good example of this. While many papers in health psychology begin by calling on

the model in what seems a systems approach, in practice the subsequent analysis rarely addresses systems aspects. One reason for this may be that psychology uses few tools that allow us to conceptualise and analyse systems.

Although systems approaches have been relatively unusual in psychology, this is not to say that they have not been used. Recently there has been interest in incorporating dynamic systems approaches into social psychology (see for example, Vallacher & Nowak, 1994a). This literature often seems to jump straight into large non-linear and chaotic systems. Unfortunately, this gives the impression that systems approaches are necessarily arcane and difficult. Contrasted with these complex methods, simpler approaches may look too trivial to be of value. This is deceptive, as complex and interesting patterns can emerge from models that appear to be simple (Holland, 1998).

This thesis outlines and demonstrates a tool, computer simulation, that we might use to implement a dynamic systems approach to a phenomenon from health psychology. Here I identify and describe a methodology, computer simulation of a dynamic systems model, and make some claims for its strengths. I also demonstrate the methodology in action, to show that it can be practicable and fruitful. This is done through a concrete example: how a change in income inequality might disrupt social relationships in a population. This forms one link in a hypothesised causal chain from income inequality to mortality mediated through damage to social relationships (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997). The example has some features that are common in problems in health psychology.

There is epidemiological evidence of a strong relationship between income inequality and mortality (Carroll, Davey Smith, & Bennett, 1996; Lynch & Kaplan, 1997; Wilkinson, 1996). This indicates that countries with a highly unequal distribution of income tend to have higher mortality than do more egalitarian countries. This is independent of their absolute wealth, and so is not readily explained by material mechanisms. Over the last twenty years income inequality has increased in many countries, including New Zealand. This might lead us to wonder how a change in income inequality might affect mortality.

One potential explanation suggests that the social fabric is disturbed in societies that have high income inequality (Wilkinson, 1996). Some evidence exists to support this. In England during the Second World War, a period of greater income equality and lower mortality also saw a population united by a strong identity and common goal (Wilkinson, 1996). People tend to trust each other less in societies with a high degree of income inequality than in more egalitarian societies (Kawachi et al., 1997). While we have evidence of trust being an important mediator, it is not obvious what mechanism might be involved. Other evidence suggests that strong social relationships are associated with reduced mortality (Berkman & Syme, 1979; House, Landis, & Umberson, 1988). We might ask whether the mechanism indicated by differences in social trust might involve an effect on social relationships.

This brings us to the first problem. While income inequality exists only as a characteristic of a population, social relationships can be conceptualised at many different levels. For instance, an individual might have a unilateral perception of being supported within a particular relationship. Between two people a relationship might be characterised by its degree of interaction, intimacy and function. Beyond that, each individual will have a wider social network of some size and composition. Finally, social networks are themselves crosslinked throughout the population to produce a connectedness between individuals in the population. For this example, we need to tie individual level data and knowledge about social relationships that we have from social psychology to a population level phenomenon like income inequality. We have few means to tie together these different levels.

The second problem is that if we want to know how a change in income inequality might affect social relationships, we have a dynamic element. Where we have changes, we have an initial response to the change, a final state and a period of transition between these. It is difficult for us to conceptualise the dynamic behaviour of psychological processes, as the methods that we use to develop theory in health psychology do not provide for or stimulate thinking in terms of dynamics.

The third problem is that the question spans economic and social dimensions. This multidimensionality is a common feature of phenomena in health psychology and

the discipline has responded by favouring the biopsychosocial model as a theoretical base. The problem is that the biopsychosocial model provides no hints as to how to link constructs in different dimensions.

Studying the effects of a change in income inequality on social relationships highlights these three features; multiple levels of aggregation, the dynamic nature of many processes, and the interaction of different dimensions. These features are not exclusive to this phenomenon, and are commonly found in health psychology. Although common, we do not have methods that give us the means to explore phenomena with these features. Dynamic systems approaches offer ways to conceptualise and model processes in such a way that they incorporate multiple levels and different dimensions. Dynamics behaviours can be explored by building models and setting them into action. The example of the effects of a change in income inequality on social relationships provides both the challenge and the opportunity to demonstrate a dynamic systems methodology.

In this case, I have used a computer simulation to model how a change in income inequality might affect social relationships. The model incorporates a small population of individuals and relationships. A network of individuals and their relationships will be governed by characteristics of both, but the dynamics of such a network are usually dominated by the characteristics of the relationships. This is partly because relationships between people are more changeable than are individual traits. It also comes from the role of relationships in making the network linkages. We might draw an analogue with a human pyramid. Individually the people participating will be steady on their feet, and able to shift their balance significantly, shifting their weight onto one foot if necessary. When they build a human pyramid they make a mesh of connections between the individuals. The dynamic behaviour of the pyramid depends on those connections. If one connection is lost through someone losing their footing the consequences will ripple though the pyramid, and it will collapse.

The model is governed by a simplified set of characteristics, derived from some observations from social psychology about the making and breaking of social relationships. The first group of these relates to who we form and maintain relationships with; people who are similar and with people who are geographically

nearby. The second group relates to decisions about maintaining or terminating relationships where the costs of maintaining the relationship have increased. In the third group, people with broken relationships will tend to change their level of participation in and demands of their remaining relationships.

Having defined the model in terms of individuals and relationships with a set of characteristics, it can be constructed. For this example, the model is constructed in the form of a computer simulation. Running the simulation programme sets the model into motion, and allows us to explore the effects of income inequality on social relationships in a population.

This example provides a demonstration that simulation can allow us to explore systems in social and health psychology. Some benefits of the methodology are demonstrated through the process of developing and exploring the model. These relate particularly to the way that we think about problems in health psychology. The initial development of the model forces us to think explicitly about the processes that might lie behind an observed phenomenon. Once the simulation has been developed, we are free to manipulate the model to try out different ideas, exploring its behaviour under different conditions. Some surprising outcomes emerge even in the development stages of the computer simulation. The development process is itself dynamic, with simulation runs feeding back some information about how a process might unfold. Running the simulation provides us both with the experience of patterns emerging from a dynamic process and with results that trigger further questions. The example demonstrates that this methodology can offer us a new way to think about the complex problems characteristic of health psychology. It forces us into a systems mode of thinking, in which we consider some processes that govern how individuals might interact.

This thesis brings together ideas from a number of different areas relating to the methodology itself and to the example that I use to illustrate the use of the methodology. I conclude this chapter with a summary of the order of presentation of these ideas.

The second chapter gives the background to this example. Most of this material is drawn from epidemiological research, where a relationship between income inequality and mortality was first reported. Some material is also drawn from the

literature concerning the effects of social networks and social support on health. The chapter goes on to explore some features of the example that make it awkward to investigate using conventional analyses. These include problems of population level analysis and of the response of a large system to changes.

The third chapter notes some features of dynamic systems, particularly their characteristics and ways that we might approach them. The fourth chapter looks more closely at the methodology surrounding modelling. These chapters prepare the ground for the use of different types of models for dynamic systems, and lay out some ideas as to how we might use computer simulations in building knowledge.

The next three chapters describe how the example might be modelled using a computer simulation. The fifth chapter gives a detailed description of the development of the model and computer simulation. The sixth chapter describes the further refinement of the model through the early parts of the simulation and goes on to present some results obtained from running the simulation. A discussion of these simulation results follows in the seventh chapter.

Finally, in the conclusion I make some comments on the potential for the use of computer simulations of dynamic systems in health psychology, and how they might shape our thinking about health psychology.