METHODS

Network analysis

David Hevey, Aifric Collins, and **Amy Brogan** on techniques to allow the mapping of belief structures

How do we make sense of the causes of events? Psychologists have long puzzled over this question, and increasingly researchers are availing of developments in network science to understand the complexity of our causal thinking. Complex causal attributions require connected attributes that have sophisticated dynamic pathways of action between them; such connections form networks, and network science offers novel theoretical tools and techniques to map such networks.

The growing interest in interconnectedness is salient for psychology as networks pervade all aspects of human psychology (e.g. Borgatti et al., 2009); research has examined fundamental psychological constructs such as intelligence (van Geert, 1998) and personality in terms of dynamic network systems (e.g. Shoda et al., 2002). Dedicated journals and conferences testify to the importance of network analysis: notably, network analysis was a programme theme at the 2011 American Psychological Society conference. Network theory offers a broad framework to productively examine complex systems across disciplines; Barabási (2012) argues that theories cannot ignore the network effects caused by interconnectedness.

Network analysis comprises various techniques for examining both how people structure their causal beliefs and the extent to which the causal understanding is shared amongst individuals (Reser & Muncer, 2004). Its application to modelling perceptions of causality in psychology was pioneered by Lunt's (1988) examination of perceived causes of examination failure; subsequently it has addressed a broad range of research questions in various psychological disciplines. Network analysis examines the pattern of relationships between causal factors and the focal event to provide a model of the perceived causal structure. For example, we could examine people's perceived causal structure for illness (focal event) using putative causes such as stress, health behaviours, personality, and exposure to pathogens.

According to Kelly (1983), the properties of a causal structure include:

- Direction of causality: causes flow from the past to the future, but can also have reciprocal effects. For example, although people may believe that stress causes illness, they may also believe that being ill causes stress.
- Extent of a cause: whether causes have proximal or distal effects. In this example, both stress and health behaviours are proximal causes, whereas personality is a distal cause. Furthermore, it is possible that another attribute may mediate the relationship between an attribute and the focal event. For example, in addition to having a direct effect on illness, stress may cause illness via its effect on health behaviours.
- Patterning: distinguishes between simple relationships, wherein a putative cause leads to one effect (e.g. exposure to illness causes the illness), and complex relationships, wherein many causes unite creating one effect (e.g. stress, exposure to pathogens, and health behaviour cause illness) or one cause leads to multiple effects (personality causes both health behaviours and stress).
- Stability: whether causes are stable (e.g. personality) or unstable (e.g. exposure to pathogens).

The perceived causal structure produced may be sparse or dense, depending upon the number of causal factors identified and the complexity of relationships present.

Network analysis techniques

Data for network analysis can be collected in a variety of ways. Although the diagram and matrix grid methods are the most widely used approaches in psychology (Knoke & Yang, 2008), more recent approaches apply formal mathematical modelling to examine both empirically generated and simulated data (e.g. Borsboom et al., 2011).

Diagram method

The diagram method involves either the spatial arrangement of cards containing causes or the participant directly drawing the structure that captures the relations among the attributes. Participants may be given a set of potential causal factors or can self-generate causal factors; some approaches provide some initial set of causal factors but encourage participants to incorporate their own personally relevant factors into their network.

The matrix grid technique

The matrix grid technique requires participants to rate the strength of (i) the causal relationship between each attribute and the focal event (e.g. 'to what extent does stress cause illness?'), (ii) the causal relationship between each attribute and

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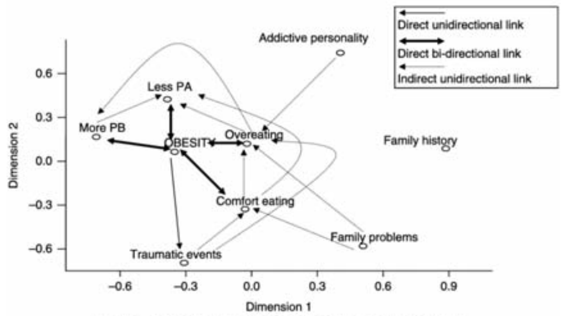

Less PA = Less physical activity; More PB = More passive behaviours

each other attribute (e.g. 'to what extent does stress cause health behaviour?'), and (iii) the causal relationship between the focal event and each attribute (e.g. 'to what extent does illness cause stress?'). The causal relationship is rated for every pair-wise combination of attributes and focal event. Such ratings can be on a binary scale (causal link either present or absent) or a continuous scale to rate the strength of each relationship. A criterion is applied to the ratings to establish which of the causal links should be regarded as consensually endorsed (based either on the percentage of respondents endorsing the network or on the mean strength of the causal relationships).

Visualisation

Although early research applied multidimensional scaling to represent the spatial structure of causal networks (Knoke & Yang, 2008), more powerful approaches have emerged based on complex algorithms to optimally represent networks; for example, qgraph (Epskamp et al., 2012) was developed in the context of the network approaches to psychopathology pioneered by Borsboom and colleagues, which is outlined in the next section.

Applications

Network analysis has been applied to diverse areas (e.g. unemployment, heart attacks, and satisfaction with friendships) to analyse causal belief structures. Research has also examined how such structures inform categorisation. For example, both clinical psychologists (Kim & Ahn, 2002a) and lay people (Kim & Ahn, 2002b) typically interpret symptom patterns for psychological disorders in terms of causal networks: disorders are characterised as clusters of causally related symptoms in a network, with some symptoms treated as more important than others. Let's turn to some examples.

Recent research from Borsboom and colleagues examined comorbidity among psychological disorders from a network perspective. By conceptualising psychological disorders as networks that consist of symptoms (e.g. depression consists of symptoms including insomnia, lack of interest, etc.) and causal relations between them, novel insights into the patterns of association among DSM-IV symptoms emerge (Cramer et al., 2010). Symptoms can be conceived as being components in a network, and not simply isolated indicators of some underlying latent condition. Consequently symptoms can have direct links with each other to reflect an underlying condition (insomnia and lack of interest are both symptoms of depression) or can have indirect links to each other that cover different conditions: lack of interest and anxiety are not directly connected in the network as there are no DSM-IV disorders that feature both of these symptoms, but these symptoms are connected indirectly via insomnia, because insomnia is a shared symptom of depression (which also has lack of interest among its symptoms) and general anxiety disorder (which includes anxiety among its symptoms). Consequently comorbidity is hypothesised to result from direct relations between symptoms of multiple disorders. Such a network model presents explanations for established patterns in research, wherein certain conditions have high comorbidity (because of the number and proximity of links between symptoms) and others have low comorbidity. Furthermore, network analysis offers insight into why the boundaries between diagnostic categories are fuzzy: if psychological disorder is best conceptualised as a network of symptoms and comorbidity is best viewed as a network of symptoms of two disorders, then boundaries are fuzzy because there are no boundaries, as the networks are connected.

Obesity is a complex multifactorial disease that is strongly associated with other chronic conditions and premature mortality. Brogan and Hevey (2009) used network analysis to examine obese individuals' causal models for the condition. Putative causes were identified and obesity was included as both the focal event and a causal factor in the study. Respondents had a highly consensual yet complex causal model (see Figure, above).

Traumatic events, family problems, and addictive personality were distal causes and their effects were mediated through overeating or comfort eating. More passive behaviours, less physical activity, overeating, and comfort eating were proximal causes and each had a direct bi-directional link to obesity; consequently obesity was regarded as having future effects on behaviours. The results highlighted that the causal model elicited focused predominantly on behavioural origins of obesity. How one attributes the causes for obesity may influence one's willingness to practise weight reduction techniques.

Conclusion

Network analysis highlights the complex causal chains by which we make sense of the world and determines the extent to which our understandings are shared by others. It offers great potential for researchers; by considering psychological processes and outcomes from a dynamical systems theory perspective, new ways of conceptualising and answering important psychological questions are available. Psychological processes reflect complex systems: to understand complex systems, we need to understand the networks that define the interactions between the constituent attributes.

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