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Assessing framing assumptions in quantitative health impact assessments: A housing intervention example[☆]

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ABSTRACT

Health impact assessment (HIA) is often used to determine ex ante the health impact of an environmental policy or an environmental intervention. Underpinning any HIA is the framing assumption, which defines the causal pathways mapping environmental exposures to health outcomes. The sensitivity of the HIA to the framing assumptions is often ignored. A novel method based on fuzzy cognitive map (FCM) is developed to quantify the framing assumptions in the assessment stage of a HIA, and is then applied to a housing intervention (tightening insulation) as a case-study. Framing assumptions of the case-study were identified through a literature search of Ovid Medline (1948–2011). The FCM approach was used to identify the key variables that have the most influence in a HIA. Changes in air-tightness, ventilation, indoor air quality and mould/humidity have been identified as having the most influence on health. The FCM approach is widely applicable and can be used to inform the formulation of the framing assumptions in any quantitative HIA of environmental interventions. We argue that it is necessary to explore and quantify framing assumptions prior to conducting a detailed quantitative HIA during the assessment stage.

1. Introduction

The extent to which an environmental policy intervention causes health-related changes is a key question in research. Health impact assessment (HIA) identifies possible health consequences of new policy interventions (de Blasio et al., 2012; Kemm, 2004; Mindell et al., 2004). HIA is an area of increasing interest to policymakers in environmental health (de Nazelle et al., 2011; Dhondt et al., 2013; Maire et al., 2012), and there is considerable scope for innovation in the application of quantitative methodologies (Fehr et al., 2012; Mindell and Joffe, 2005). Underpinning any HIA is the framing assumption, which defines the causal pathways mapping environmental exposures to health outcomes. However, the sensitivity of the HIA to the framing assumptions is often ignored in many assessments. Framing assumptions are inevitable when quantifying the health effect of an environmental intervention.

Housing interventions such as improving housing insulation to reduce heat loss are examples of environmental policy interventions. Improving housing insulation, as an energy efficiency measure, is encouraged as part of the UK housing regulations to reduce carbon emission and energy cost (DCLG, 2003). Insulating homes is not only justified on energy efficiency grounds alone, but can also be justified on health grounds. Energy efficiency measures can benefit health through increasing indoor temperature in winter (Barton et al., 2007; Wilkinson et al., 2007). However, changes in the indoor environment as a result of reducing permeability can also affect health adversely. If improving insulation is not accompanied by adequate ventilation, there is the risk of increasing indoor pollutant concentrations (Bone et al., 2010).

Housing interventions are examples of complex (environmental) interventions (Craig et al., 2008). There is no unique definition of a complex intervention. In general, a complex intervention has multiple direct and indirect pathways in which it can affect health (Campbell et al., 2000). The pathways associating a complex environmental intervention with health can also be ill-defined and there are often multiple health outcomes.

HIA has been used to determine the health impacts of housing policy and interventions (Wilkinson et al., 2009a). However, large uncertainties can arise in HIA models from the lack of understanding of the complex associations between the indoor environment and health. Sources of uncertainty can include the framing assumptions associated with the formulation of the HIA, in addition to the more known sources of analytical uncertainty associated with the parameters and the structure of the models (Mesa-Frias et al., 2013).

Framing assumptions arise at the "conceptualisation" of the HIA model formulation (Briggs et al., 2009), and define the causal assumptions underpinning the assessment. The framing assumptions are typically ignored when appraising the uncertainty in many assessments by discarding factors that one considers unimportant (Briggs et al., 2009; Ramsey, 2009). Since the outcome of a HIA can be highly sensitive to the choice of the framing assumptions made initially in

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the assessment stage, it is important to characterise and quantify these framing assumptions.

Mathematical methods can be used to quantify the framing assumptions when defining the context of the assessment in evaluating the health impact of environmental interventions, ex ante. The use of complex system mathematical models has been proposed in public health (Galea et al., 2010; Joffe et al., 2012; Shiell et al., 2008). This paper demonstrates the use of another type of complex system modelling approach, known as fuzzy cognitive mapping (FCM). In this study, we use FCM to quantify the framing assumptions in the assessment stage of a HIA model of housing insulation, as a case-study example. The approach however is widely applicable to other examples of complex environmental interventions.

2. Overview of FCM method

A cognitive map is a conceptual graphical model used to represent causal assumptions (Kitchin, 1994; Wood et al., 2012). Cognitive maps have been used for conceptual modelling in many areas in the social sciences, such as in assessing the social implications of nanotechnologies and in describing social knowledge in the political sciences (Axelrod, 1976; Nakagawa et al., 2010). Cognitive maps can be extended to incorporate imprecise qualitative knowledge into quantitative variables, known as fuzzy cognitive maps. Fuzzy cognitive maps (FCM) have been used as a modelling tool to represent conventional and Aboriginal perspectives on the determinants of diabetes (Giles et al., 2007).

In this study, FCM is used to model framing assumptions quantitatively. Framing assumptions can be first explored with the use of causal diagrams. A causal FCM diagram shows the connections between variables in the "system of interest" and can be used to define the context of the assessment in which the environmental intervention is applied. The main emphasis of using causal FCM diagrams is on identifying causal pathways as they relate to health outcomes.

In general, FCM diagrams are directed graphs, which indicate directional interactions in the causal pathways. Fuzzy cognitive map diagrams are described by a set of nodes and their causal relationships (links). In the context of this study, each node represents a key indoor factor, a health or a non-health outcome. The relationships between the nodes are described through directional links or connections. Positive (+) and negative (−) signs imply positive and negative causal relationships, respectively. A positive causal link between a pair of nodes means that when the amplitude (level) of one node increases, the amplitude of the other increases. A negative causal link, on the other hand, means that when the amplitude of one node increases, the amplitude of the other node decreases. A value zero (0) between a pair of nodes implies that there is no causal link between the nodes.

A FCM was developed here to model the framing assumptions in the assessment stage of a HIA model of housing insulation. Fuzzy cognitive maps were then used to investigate the causal interactions and explain semi-quantitatively how intervention-related changes in the indoor environmental exposures can potentially affect health. Our methodological approach developed in this study is described in five main steps below.

3. Five steps in assessing framing assumptions

The five main steps in assessing framing assumptions are: (1) synthesising the evidence on causal pathways from the literature; (2) constructing the causal diagrams from individual studies identified from the literature; (3) representing mathematically the combined causal diagram as a system matrix; (4) measuring the structural properties of the system matrix; and (5) simulating causal processes. Details of the steps are described below. Refer to Appendix A for detailed mathematical description of the steps and Appendix B for a walk-through example.

3.1. Synthesising the evidence on causal pathways from the literature

Health-relevant factors and outcomes were identified in the literature to construct causal diagrams that define nodes and inter-nodal relationships. A literature search of Ovid Medline (1948–2011) was conducted using the search terms: "housing" combined with "insulation" and "health" to identify studies investigating factors and outcomes (nodes) influencing the relationship (links) between housing insulation and health. Causal pathways associating housing insulation and health were identified qualitatively. An additional hand search of the literature was conducted in Ovid Medline using the identified key factors and outcomes as search terms to determine quantitative information on the associations.

3.2. Constructing the causal diagrams from individual studies identified from the literature

Based on each published study retrieved from the literature — nodes were identified. An individual casual diagram was constructed and positive or negative associations between the nodes of the diagram were determined. Measures of effects, such as odds ratio, were subsequently used to quantify the strength of the causal association between the nodes. The measures of effects ("causal weights") were noted with each connection between a pair of nodes to represent the strength of the effects, using either the natural logarithm of an odds ratio for a health outcome, or the percentage change in indoor factors or outcomes obtained from retrieved studies in the literature (Appendix A.1).

3.3. Representing mathematically the combined causal diagram into a system matrix

Each causal diagram was then mathematically translated into a "connection matrix." The elements of each connection matrix correspond to the measure of effects between each pair of nodes (causal weights). Each element is an algebraic number, which can be positive or negative. The value zero (0) means that there is no causal link between the nodes. The matrices from each published study were combined through summation and their values were then normalised (by dividing each element by the absolute maximum across all elements) to create a "system matrix" in which each element was in the range −1 to +1 (Appendix A.2).

3.4. Measuring the structural properties of the system matrix

The structural properties of the system represent the causal interpretations, mapping the pathways in the diagram. Indices are numerical measures, calculated using graph theory (West, 2000), which characterise quantitatively the structural properties of the system. A "centrality index" shows how well connected a node (indoor factor or an outcome) is in relation to other nodes, i.e. how many links join with this specific node. The centrality index measures the centrality of the framing assumptions defined in the assessment. A high centrality index indicates high importance, whereas a low centrality index means less relevance in the system. Nodes are classified according to their input and output values (which are signed causal weights entering or leaving a node, respectively). Those nodes with only input values (i.e. arrows directed to them) can be viewed as the "outcomes" while nodes with only output values (i.e. arrows directed from them) may be viewed as the "drivers" or "stressors". Nodes with both input and output values can be viewed as "mediating factors" playing both roles. The centrality index is calculated by summing the magnitude of the total input and output values in the system (Appendix A.3).