Original Article

Ontologies of behaviour: Current perspectives and future potential in health psychology

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This article is based on a roundtable discussion at the European Health Psychology Conference in Bratislava in August 2022. The roundtable sought to increase awareness of how ontologies have and could be used by health psychologists to answer questions about behaviour.

What are ontologies?

To advance behavioural science, we need to improve our methods for specifying the things that we study, including behaviour, and the relationships between them. As a recent report by the National Academies of Sciences, Engineering, and Medicine noted: "Progress in the behavioural sciences has been hindered by the use of different terms or descriptions for the same underlying entity or condition; the use of the same term for different entities or concepts; the use of different, poorly correlated measures for the same entity; and the use of measures whose relationship to the phenomena they are measuring is not well understood." (NASEM, 2022, p. 2).

Taxonomies provide a starting point for addressing this issue. In the social sciences, taxonomies are classification systems that group entities (e.g., concepts, objects, processes, and their attributes) by similarity, typically using data (Bailey, 1994). Several taxonomies related to behaviours exist, such as the Behaviour Change Techniques Taxonomy v1 (Michie et al., 2013), the Health Behaviour Taxonomy (Nudelman & Shiloh, 2015) and the International Classification (IC)-Behaviour (Larsen et al., 2021). However, "taxonomic definition is not the same as an adequate description, explanation or analysis of a class of types" (Hodgson, 2019, p. 213); in part because taxonomies rarely delineate the various relations between classes and may lack a logical basis.

Ontologies go beyond taxonomies. They are ways of representing the world that include definitions of uniquely specified categories or classes of entity and their properties, which are characterised as relationships with other classes of entity (Hastings, 2017). Thus, each class of entity in an ontology has: (1) a unique and unambiguous identifier, (2) a label that indicates what the class encompasses, (3) a definition of the class, and (4) a set of defined relationships with other classes of entity. Ontologies are typically hierarchically arranged networks of classes, with some classes being the 'children' of 'parent' classes (e.g., the behaviour 'waltzing' might be a child of the parent class

'dancing'). The formal structure of ontologies allows computerized searching and integration of data, as well as automated inference. For this purpose, a logic-based language for encoding ontologies has been developed, the Web Ontology Language (OWL, W3C, 2012).

What is the added value of using ontologies?

Ontologies are widely used in many areas of science, notably the Gene Ontology in biology (Ashburner et al., 2000). Ontologies have the potential to address issues that are central to health psychology, including uniting different disciplines, languages, and users (e.g., lay vs. expert) by mapping different terms to describe the same idea (referred to as the 'Jangle fallacy', Kelley, 1927). Ontologies allow different users to agree on the same semantic-free identifier (or unique ID), while allowing for different labels in different namespaces to reflect different practices of usage. OWL even has built-in support for language tags, meaning that it is possible to track how different languages refer to the same concept.

Ontologies can help conceptualise behaviour, interventions, and outcomes, understand the relationships between behaviours, and organise and integrate evidence. Ontologies enable more precise specification of behavioural outcomes and their measurement and provide a way to represent behavioural attributes that can elucidate relationships between them. Ontologies can also facilitate the interpretation and use of evidence by allowing data and evidence to be inspected and interpreted at different hierarchical 'levels'. This enables studies with diverse assessments of behaviour to be aggregated by aligning their outcome measures at an appropriate level.

Ontologies also help identify gaps in evidence (in one sense, ontologies act as maps from which to find unchartered territory), facilitate clear reporting through the use of precisely defined shared concepts, and generate testable hypotheses. For example, using an ontology as a structure for investigating how behaviours are related could help to identify 'core' or 'central' behaviours (behaviours that are likely to co-occur with others and potentially influence them, Nudelman et al., 2019) that can offer targets for interventions.

Use of ontologies to characterise behaviours

Several ontologies cover behaviours with varying levels of detail and scope (see reviews by Baird et al., 2022, and Braun et al., 2022). However, many ontologies to date do not adhere to principles of good ontology practice (as defined by the Open Biological and Biomedical Ontology (OBO) Foundry, Smith et al., 2007) (Braun et al, 2022). For example, only three of the 28 ontologies identified by Baird et al. (2022) included definitions. It is, however, fair to note that the development and use of ontologies in the social sciences – and health psychology in particular – is still in the early days and new projects are addressing the limitations of past approaches. Below, we describe two examples discussed during the roundtable.

The Human Behaviour-Change Project (HBCP) has developed the Behaviour Change Intervention Ontology (or BCIO), which seeks to provide a comprehensive, systematic framework for representing behaviour change interventions, target populations, settings, target behaviours, and mechanisms of action. It also provides a way to describe intervention evaluations, including study design and study features that affect risk of bias. For example, Encantado et al. (2022) used the BCIO to code features of digital behaviour change interventions for weight loss (e.g., tailoring) and how they were delivered (using the Mode of Delivery ontology v1, Marques et al., 2020).

The TURBBO Project uses ontologies of behaviour

as a framework for examining the relationships between behaviours (Scott et al., 2022). The project has developed an upper ontology that specifies the attributes of behaviour (e.g., that behaviours can be habitual, effortful) that will be linked to existing ontologies that classify and distinguish behaviours. Online tools are being developed that will enable the community to provide information on the relation between specific concepts within the ontology (e.g., a researcher who conducts a study that measures consumption of fruit, vegetables, and alcohol will be able to add the correlation between these behaviours). Further tools will then enable users to query the knowledge base to estimate the relationship between behaviours at different levels (e.g., between physical activity and diet, or more specifically, between walking and carbohydrate intake), similar to tools for conducting dynamic meta-analysis (Shackelford et al., 2021) in other fields (e.g., Röseler, Körner, & Schütz, 2021).

Challenges to developing ontologies of behaviour

Developing and maintaining ontologies presents challenges, including whether to take a top-down approach to development (e.g., drawing on theory, expert consensus) or bottom-up approach (e.g., statistical clustering of data), how to manage overlap between ontologies, how to map and combine ontologies, and how to update and maintain ontologies. Some of these challenges are addressed below in the section on recommendations (e.g., we suggest that ontologies be built on a common foundational layer, that unique IDs are assigned to concepts), but we start with some conceptual challenges – specifically, that the precise specification that is the strength of ontologies can pose fundamental questions to those working in a discipline about the ideas that they study and work with.

To take a specific example, developing an ontology of behaviour needs to address several challenges: (1) Researchers and practitioners may want to classify behaviours in different ways depending on the purpose of the classification (e.g., 'walking' could be a 'health behaviour', a form of 'physical activity', 'locomotive behaviour', 'commuting behaviour', or even 'expressive behaviour'). (2) Behaviours need to be represented at multiple levels (e.g., 'smoking' can refer to a single episode or repeated episodes over years). (3) We often want to treat not doing things as behaviours (e.g., 'stopping smoking' or 'abstinence from smoking'). (4) Fully characterising behaviours requires more than saying what class they belong to; accurate descriptions of behaviour involve specifying multiple attributes (e.g., a start point, an end-point, intensity, patterning). To address these challenges, the Human Behaviour Ontology as part of the BCIO uses a hierarchy of behaviour classes based on parent classes to which the behaviour will always belong, together with the opportunity to create 'logically defined classes' for specific uses that combine class membership and attributes (e.g., the class 'walking' is always a locomotive behaviour; while a class 'walking for health' is a logical combination of 'walking' and 'health-promoting behaviour').

Recommendations for health psychologists using and working with ontologies of behaviour, including consideration of methods for developing ontologies

It is clear that ontologies have great potential in the behavioural sciences. However, behavioural scientists will need help to engage with ontologies, particularly if they are not working in collaboration with computer scientists or ontology experts. Shared tools for compiling and working with

ontologies dedicated to the behavioural and social sciences community will help in this regard and this work is underway in the form of the Behavioural and Social Sciences Ontologies (BSSO) Foundry (http://www.bssofoundry.org/): If you are interested in joining this 'community of practice' do sign up and get involved with activities that will be developed over time. Tools for using ontologies are also being developed by the TURBBO and HBCP teams, such as the Ontology Visualisation tool for BSSO ontologies (http://vis.tools.bssofoundry.org/).

Another recommendation is to build ontologies that share the same foundational layer (or 'upper level ontology'), to ensure that they are interoperable, yet can each focus on a different aspect of the overall domain as needed. One suggestion is that this be the Basic Formal Ontology (BFO, https://basic-formal-ontology.org/), which is widely used and serves as the recommended upper level for the OBO Foundry collection of ontologies, facilitating interoperability across domains. It is also used by the BCIO.

Finally, we will need ways to handle the constantly changing, dynamic nature of ontologies. That is, ontologies need to be responsive to improvements and edits, yet provide people with a specific and stable way to refer to entities. This is achieved by strict principles for the evolution of the content: Unique IDs are assigned to entities (such as BCIO:036000 for 'individual human behaviour' in the BCIO). If subsequently refined or subdivided, then new entities are created with new unique IDs that refer back to the original entity, while preserving the original (legacy) entity and ID. For example, the upper ontology in the TURBBO project modelled DOI (digital object identifier) as a class with a new URI (https://purl.org/turbbo/upper_0000149), but added a link to its original URI in the DataCite ontology (http://purl.org/spar/datacite), where it was used as an instance of a class (http://purl.org/spar/datacite/doi). Unique IDs therefore provide a way to refer to entities unambiguously, and link entities between ontologies.

There are plans to establish a Special Interest Group within the European Health Psychology Society for health psychologists working with, or interested in, ontologies. Readers are invited to contact Alison Wright (alison.j.wright@ucl.ac.uk) if they are interested in joining this group.

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