

Developing an ontology to serve automated analysis of cross-disciplinary literature for the Human Behaviour-Change Project

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1. About the Case Organization

The 6-year Human Behaviour-Change Project, a collaboration between behavioural and computer scientists, developed an ontology-based Knowledge System for predicting outcomes of behaviour change interventions, applied to a first use case of interventions to help people stop smoking.

2. About the Challenge

We need more effective interventions to enable behaviour change to address the big threats facing humanity such as climate change. We have more than 100 studies evaluating the effectiveness of behavioural interventions published every week.

However, the ability to provide evidence-based answers is limited by difficulties in finding & extracting the evidence relevant to any particular question, synthesising evidence to answer real-world questions posed by policy makers, practitioners etc. and doing this at scale and speed so that evidence is comprehensive and up-to-date. One of the big challenges in extracting and synthesising the evidence is that research is reported in highly heterogenous ways, with terminology imprecisely defined and used differently by different groups, and key information is often omitted. This hinders the accumulation of knowledge.

The ultimate aim is to provide policymakers, planners, practitioners, researchers and other users with automated tools to search all relevant evidence to answer variants of the question: “When it comes to behaviour change interventions, what works, compared with what, for what behaviours, how well, for how long, with whom, in what setting, and why?”.

3. What We Did

We aimed to develop a comprehensive ontology for the domain of behaviour change interventions and apply this ontology to annotate studies of smoking cessation interventions. A team of behavioural scientists and an ontology expert identified the scope of the ontology and its lower-level ontologies.

We developed it using literature annotation and expert discussion to develop prototype lower-level ontologies covering the content and delivery of behavioral interventions, their mechanisms of action and target behaviours, and the population and setting. We were guided by principles of good practice for ontologies¹.

Expert and user feedback on the prototypes led to further discussion and revision, with the final stage being inter-rater reliability of using it to annotate unseen literature. This last stage was innovative in ontology development and is described in Wright et al².

¹ Norris, E., Finnerty, A.N., Hastings, J. *et al.* A scoping review of ontologies related to human behaviour change. *Nat Hum Behav* **3**, 164–172 (2019). <https://doi.org/10.1038/s41562-018-0511-4>

² Wright A.J., Norris E., Finnerty A.N. *et al.* Ontologies relevant to behaviour change interventions: a method for their development [version 3; peer review: 2 approved, 1 approved with reservations]. *Wellcome Open Res* (2020), 5:126 (<https://doi.org/10.12688/wellcomeopenres.15908.3>)

The ontology and annotated dataset were then used together as input to a novel rules-based machine learning approach to develop a predictive model that is able to predict the outcomes of hypothetical intervention scenarios.

4. Challenges and Lessons Learned

There was a steep learning curve for behavioural scientists who had no prior knowledge of ontology development so progress was slower than would have been the case had they had ontological expertise. They learnt on the job, guided by our ontology expert. For example, ontological definitions are difficult to write well and we wrote a brief article to help with this³.

There is often a tension between ontological purity and comprehensible language and this often led to discussions about how best to represent entities linguistically.

Thirdly, the different experiences and perspectives of group members meant that differences in how best to organise entities or express terms emerged. They were resolved by lengthy discussion with patience on all sides. The fact that the group had good working relationships and were interested in and respectful of different perspectives helped; had this not been the case, less progress would have been made and certainly less job satisfaction would have been had.

Lessons Learned

The need for a guide to ontologies for social and behavioural scientists: we are halfway through writing this. Next time, ensure someone has responsibility for keeping a cumulative log of the principles and rules of thumb we were developing and agreeing and ensure that people consulted this so that ontology development was as efficient as possible.

Our advice would be to ensure that you have excellent support from one or more ontology experts who understand the domain being represented, and that everyone has training. We have produced a series of [webinars](#) and [training videos](#) hosted by YouTube that will help. Give enough time to discuss any problems or concerns that people have so that everyone feels listened to and included in decision-making.

5. Impact and Benefits

We have produced the world's first ontology of behaviour change interventions, the Behaviour Change Intervention Ontology (BCIO), comprising an upper-level ontology and 11 lower-level sub-ontologies. These range in depth from 3 to 8 levels, with a total of 1481 entities and 1268 relationships. These are available on [GitHub](#) and the associated papers on an [open-access platform](#).

The BCIO has been described by the US National Academies of Sciences, Engineering and Medicine as the most semantically developed in the behavioural sciences⁴. We have also produced a [website](#) and tools to increase accessibility such as a [search tool](#) and [visualisation tool](#).

No-one else has set out to do what we have done. Time will tell how much difference we make, as we will only have completed all the work by the end of this year.

³ Michie S, West R, Hastings J: Creating ontological definitions for use in science. *Qeios*. (2019). doi:10.32388/YGIF9B

⁴ National Academies of Sciences, Engineering, and Medicine. (2022). *Ontologies in the Behavioral Sciences: Accelerating Research and the Spread of Knowledge*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/26464>.

The key success factor was a dedicated group with complementary skills and effective leadership, combining task-focused with people-focused.

6. Next Steps

We are applying for NIH funding to extend the ontology across behavioural domains, to include key aspects of study methodology and to increase interoperability with other ontologies and data sets. We plan also to co-produce tools and resources to make it easier for a wide range of groups to use the BCIO.

References

1. Norris, E., Finnerty, A.N., Hastings, J. *et al.* A scoping review of ontologies related to human behaviour change. *Nat Hum Behav* **3**, 164–172 (2019). <https://doi.org/10.1038/s41562-018-0511-4>
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