ibtn
international
behavioural
trials network

Building an ontology of behaviour change interventions

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The Human Behaviour-Change Project

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Participating organisations

UCL

UNIVERSITY OF ABERDEEN

UNIVERSITY OF CAMBRIDGE

IBM Research

www.humanbehaviourchange.org

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Acknowledgements: The collaboration

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	Behavioural science	Computer science	System architecture
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The primary goal of Behavioural Science

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To develop an understanding of human behaviour to answer variants of the 'big 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?

The problem

"Messy" evidence, growing faster than humans can keep up with

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The problem

"Messy" evidence, growing faster than humans can keep up with

Messy evidence gets turned into well organised, useful scientific insights

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- Up to date estimates of the effectiveness of behaviour change interventions
- Unpacking reasons for heterogeneity in intervention effectiveness
- Generating new testable hypotheses about behaviour change

The problem

"Messy" evidence, growing faster than humans can keep up with

What the HBCP does

Artificial Intelligence
Natural Language Processing
Machine Learning

Messy evidence gets turned into well organised, useful scientific insights

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The problem

"Messy" evidence, growing faster than humans can keep up with

What the HBCP does

Ontology provides organising structure to guide

Artificial Intelligence
Natural Language Processing
Machine Learning

Messy evidence gets turned into well organised, useful scientific insights

- Up to date estimates of the effectiveness of behaviour change interventions
- Unpacking reasons for heterogeneity in intervention effectiveness
- Generating new testable hypotheses about behaviour change

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Ontology

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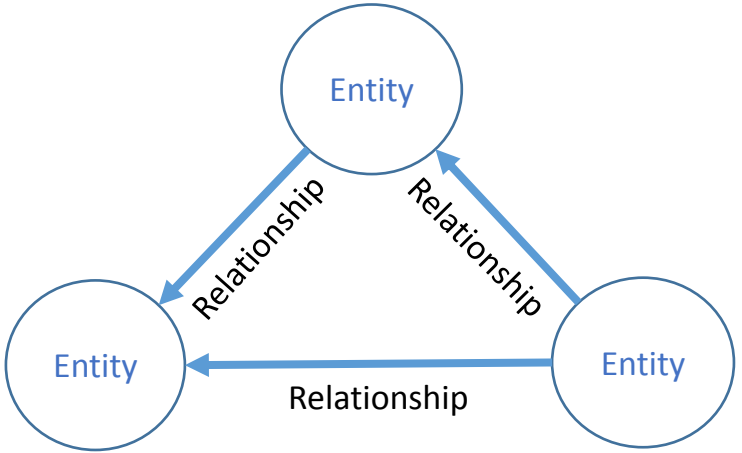
In information science, a system for representing knowledge in the form of:

1. A set of unique identifiers of ‘entities’
2. Labels and definitions for these
3. Specification of relationships between them (‘is a’, ‘part of’, ‘positively influences’ …)



Arp R, Smith B, & Spear AD (2015). Building ontologies with basic formal ontology. Cambridge: MIT Press.

Causal connections between entities within a behaviour change intervention scenario

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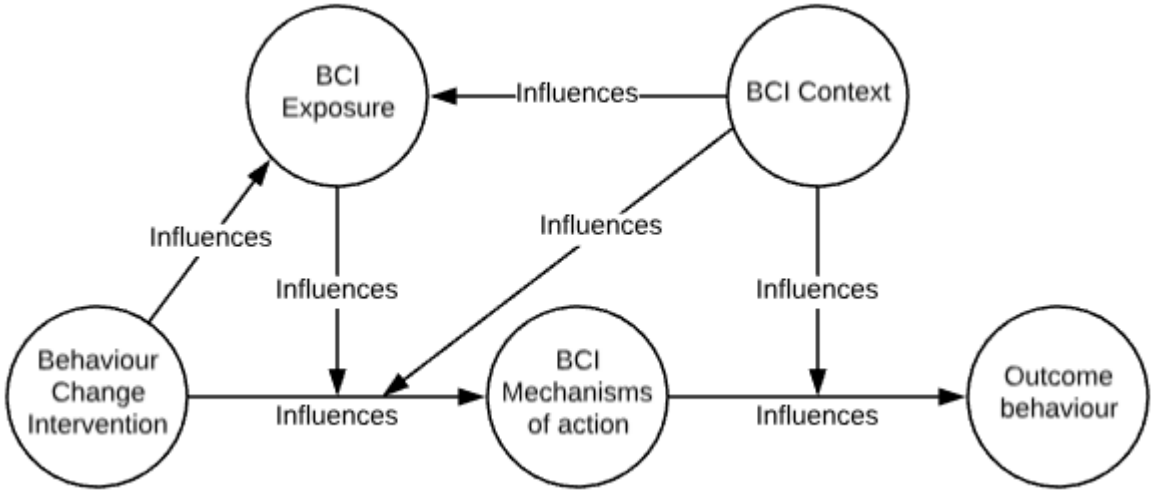

Upper level entities in BCIO

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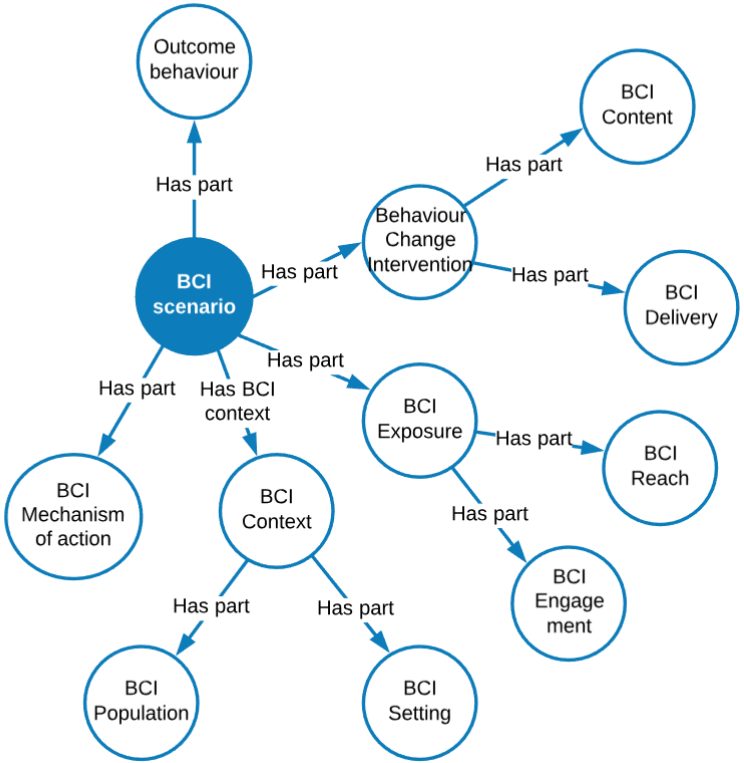

The BCI scenario

Upper level entities in BCIO

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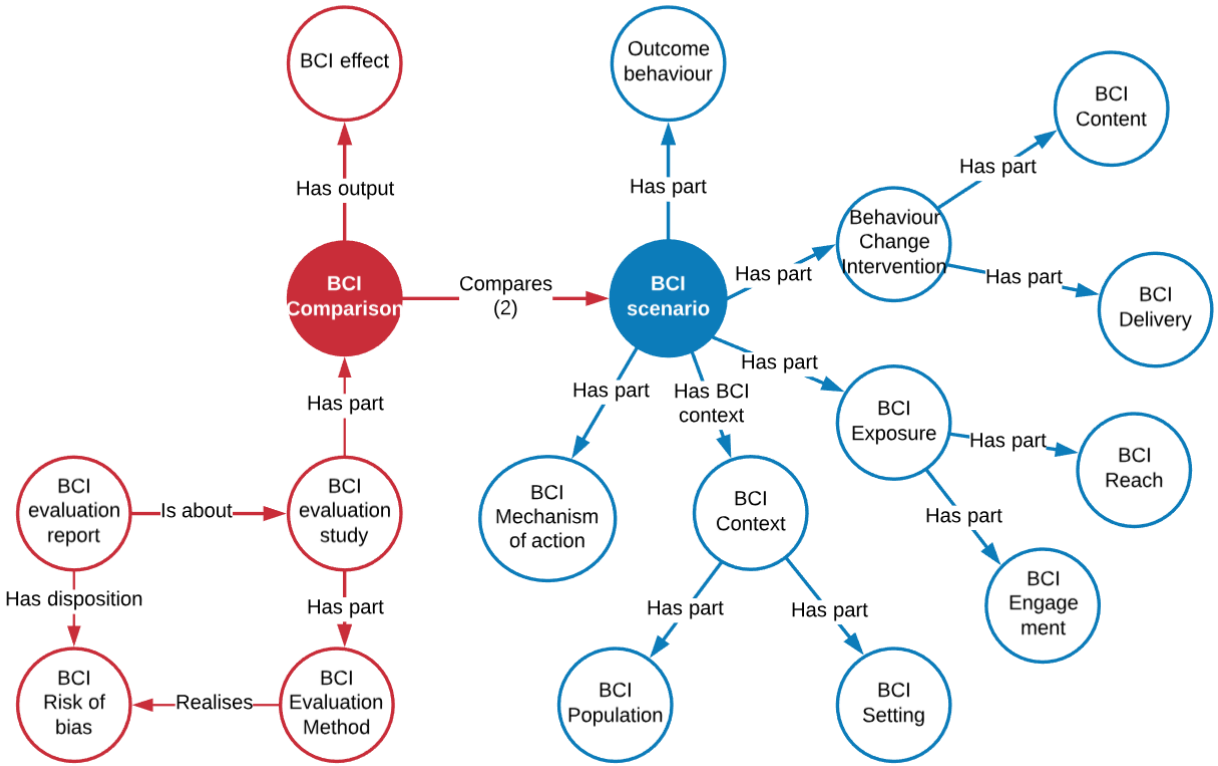
The BCI comparison



The BCI scenario

Use of ontologies: in the HBCP

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1. To annotate intervention reports, building the knowledge base for the HBCP
2. To facilitate algorithms performing reasoning and inference about data on the effectiveness of interventions
3. To help users frame questions to ask of the knowledge system?
   - e.g. ontology may serve to structure drop-down menu options in the query interface

In other research projects …..

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1. In systematic reviews to classify features of the included BCI evaluations and examine the impact of these features on intervention effectiveness
2. To provide consistent terminology facilitating better reporting of all aspects of intervention evaluations
3. To provide prompts to encourage researchers/practitioners to consider all aspects of intervention and evaluation design ahead of conducting their studies
4. For authors to self-annotate their evaluation reports, facilitating easier automated research synthesis efforts and “living systematic reviews”
5. In authoring tools for researchers to use when preparing reports on interventions

Approaches to developing ontologies

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- Top down
  - Build on previous research efforts to develop ontologies
  - Reuse of existing ontologies and/or controlled vocabularies where relevant
- Bottom-up
  - Examine relevant published reports, noting down all aspects of relevant entities/attributes/processes
  - Annotate reports to extend coverage and identify unclear definitions in early versions of the ontology

Developing the ontology: general

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1. Establish domain and scope of the ontology
2. Identify entity types and relationship types that need to be represented
   a. From research reports and models of behaviour change
3. Decide on labels and definitions
4. Establish relationships between entity types
5. Test against applicability, usability and comprehensiveness
6. Repeat steps 2 - 4 to modify and add entity types and relationships as needed

External consultation
- Ontology experts
- Stakeholder review

More detailed steps

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1. Define ontology entity (e.g ‘population’)
2. Research
   a. how entity described in behaviour change evaluation reports
   b. terms from existing ontologies
3. Map out initial ontology structure
4. Test with annotations of intervention papers and revise
5. Repeat stages 3 & 4 until ontology terms stable
6. Ontology expert review and revise
7. Stakeholder review and revise
8. Mass Annotation (300 papers), checking inter-rater reliability
9. Publish in OBO Foundry

- Ontologies will always be under revision and open for discussion

Developing lower levels of the BCIO

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Search existing ontologies for relevant terms [via Ontology Lookup Service, Bioportal]

Search for existing taxonomies or controlled vocabularies that can be employed

Look at key dimensions of the entity as reported in a small sample (50-60) BCI reports

If new dimensions still emerging, do 10 more

Critically appraise existing resources: Do they

- Provide definitions for all terms?
- Use expert consensus?
- Use data driven approaches?
- Have a maintenance strategy?

Initial draft of the ontology

Scoping Review to answer …

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1) What existing ontologies exist related to human behaviour change?
2) What methods were used to develop these ontologies?
3) What is the quality of these ontologies?

Pre-registration of review: PROSPERO (CRD42017079990)

Scoping Review Methods

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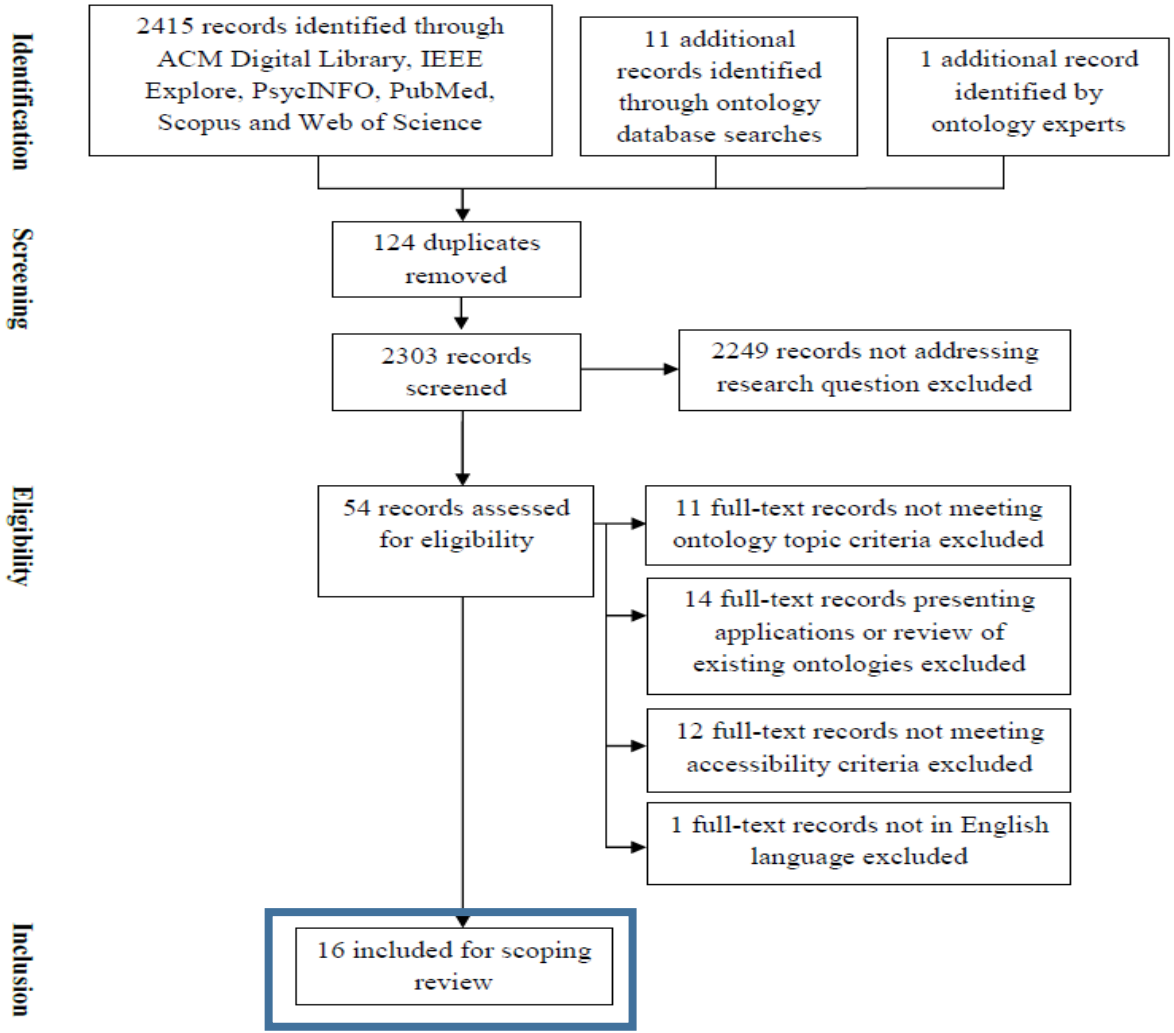
1) **Electronic bibliographic databases**: ACM Digital, IEEE Explore, PsycINFO, PubMed, Scopus, Web of Science

   - Keywords: ontology, health and behaviour.

2) **Key ontology sources**: Ontology repositories (e.g OBO Foundry, BioPortal), Cochrane's PICO ontology and medical vocabularies (e.g SnoMED CT)

3) **Expert consultation**

Inclusion criteria: relevant topic, describing development of ontology, downloadable ontology, English language



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What existing ontologies exist related to human behaviour change?

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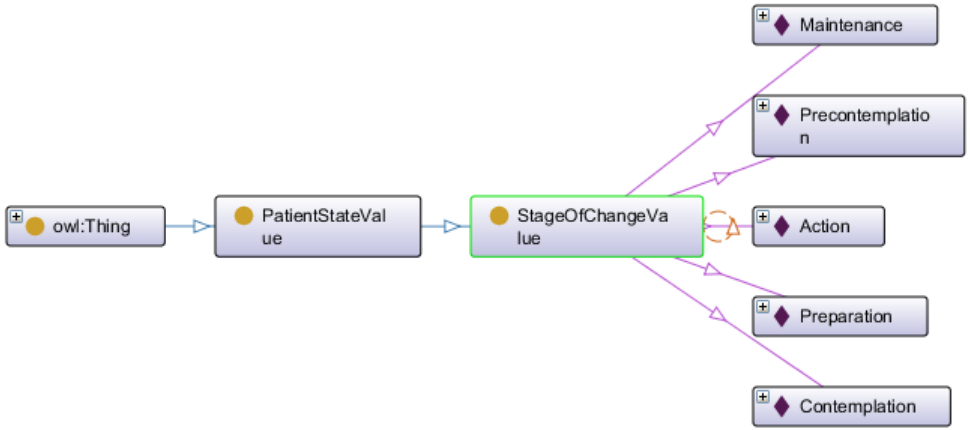
Example: Health Behaviour Change Ontology: Bickmore et al. 2011; *J Biomed Inform*.

- Developed for automated behaviour change counselling
- Focused on understanding client-patient relationship

X – incomplete representation of theories & concepts
X – not updated



What methods were used to develop identified ontologies?

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Incorporating existing resources			Techniques	
Taxonomies	Terminologies	Ontologies	User feedback	Data-driven
3/16	5/16	11/16	7/16	5/16

What methods were used to develop identified ontologies?

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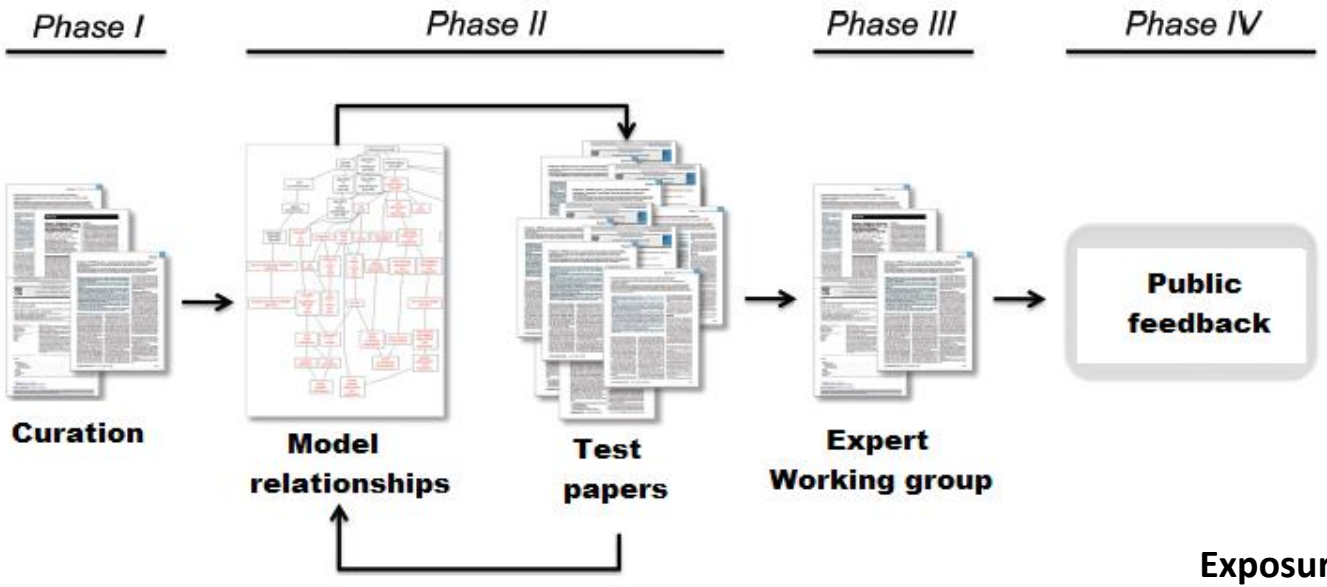

Exposure Ontology
Mattingly et al. (2012). *Environmental Science & Technology*

What is the quality of these ontologies?

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Criteria for ontology adequacy				Criterion on content
Uses unique identifiers (URIs) for each class	Clear definitions for all terms	Well-organised, hierarchical structure	Maintained (usually by a community)	Comprehensive for human behaviour change interventions
12/16 (75%)	10/16 (62.5%)	14/16 (87.5%)	10/16 (62.5%)	0/16 (0%)

- 9/16 identified ontologies available on OBO Foundry = higher quality
- Need for comprehensive, high quality ontology for BCIs

Repeated batches of annotations and revisions

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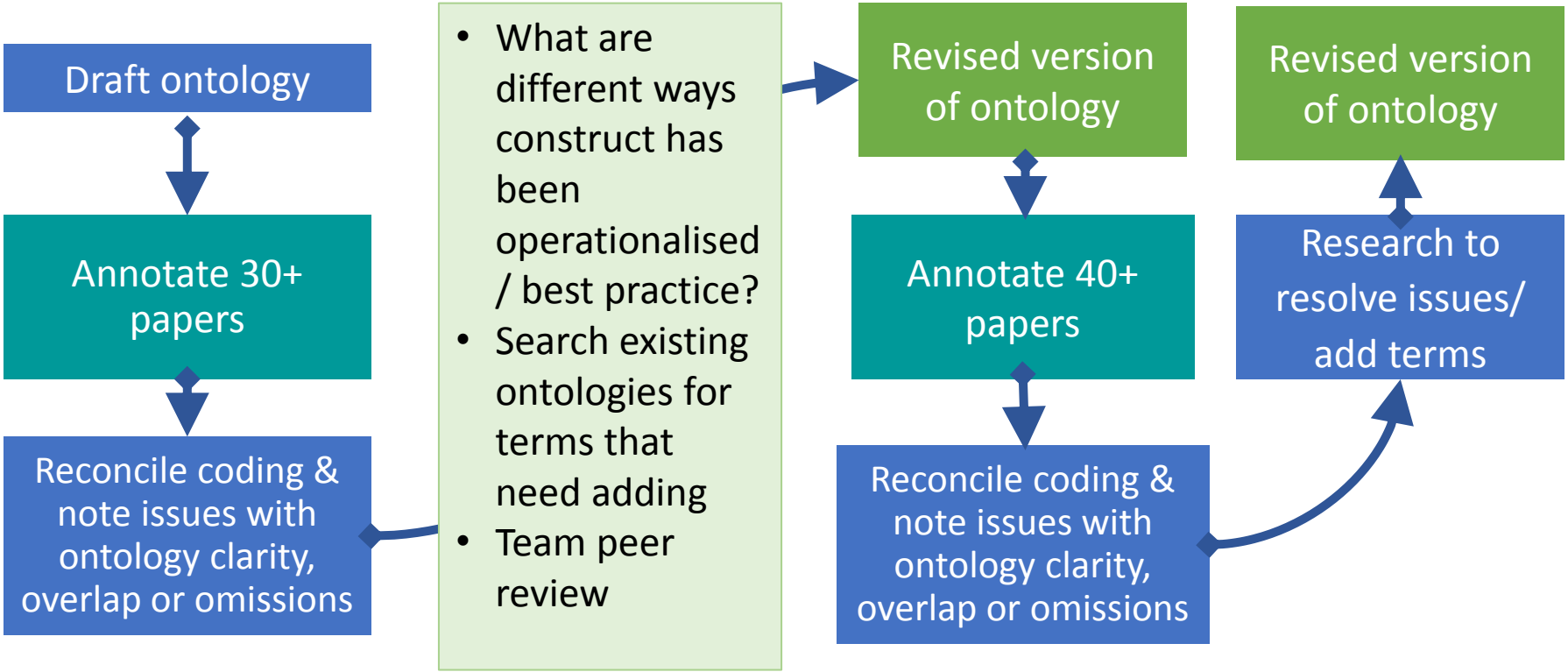

From manual to automatic annotation

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- To develop the automated feature extraction system, we need a “training set” of reports, manually annotated in terms of the BCIO entities
  - Provides a “ground truth” against which the accuracy of the automated feature extraction system can be compared

Annotations in practice

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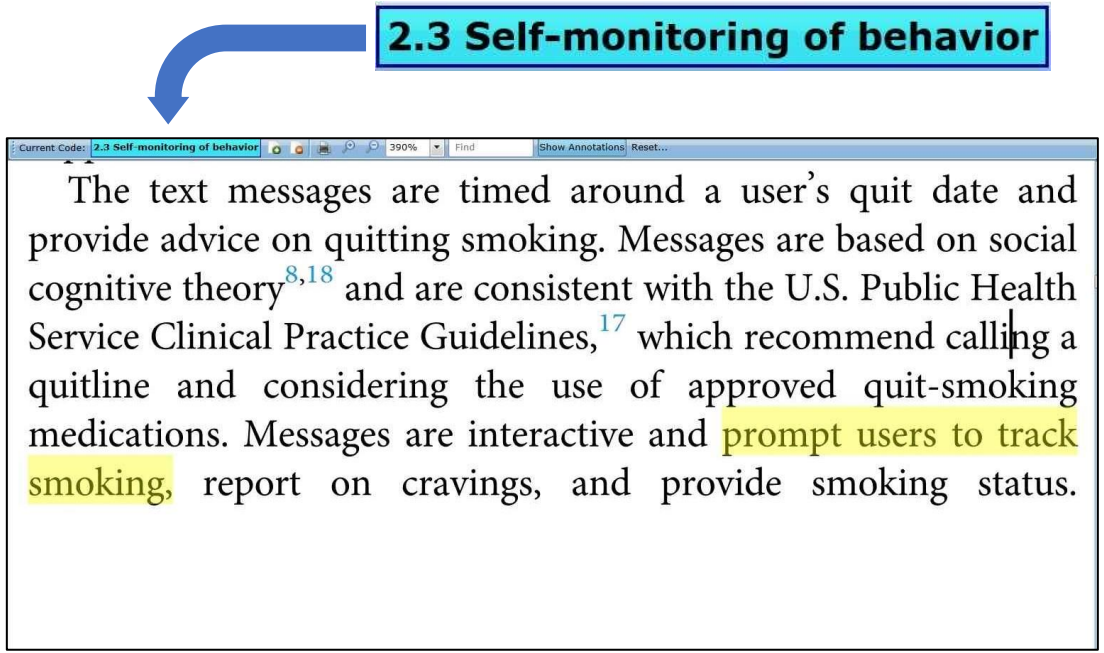
- Two researchers annotate the same batch of intervention reports for a given lower level ontology
  - e.g. Population, setting
- Online, using EPPI Reviewer software
- Once annotations agreed, resulting data is exported as a JSON file



Using annotations in ontology development

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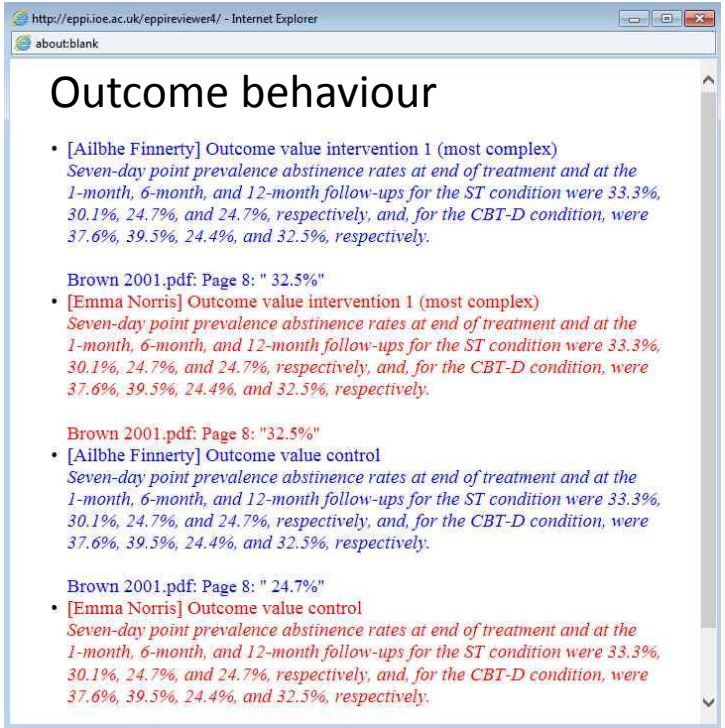
- The two annotators compare their coding
  - Resolve differences
  - Where do differences arise from?
    - Clarity of definitions?
    - Overlap between supposedly different categories?
  - Were there elements of a report that didn't seem to fit the ontology?
- Enhance ontology as required
- Try out refined ontology by using to annotate another batch of reports



Test inter-rater reliability of annotations

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- To assess whether human coders consistently apply the ontology to published intervention evaluations
- Iterative process
  - revising annotation guidance and the lower level ontology, and
  - coding further batches of papers, until achieve good inter-rater reliability

Annotate papers for a different behaviour

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- Purpose: to check how well the lower ontology functions for a broader range of BCIs
  - e.g. smoking and physical activity
  - Test comprehensiveness of coverage
- Are there issues that become apparent when annotating for physical activity that weren't apparent when annotating smoking papers?
- Research solutions as required and revise accordingly

Annotation challenges

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- Missing information in description of studies limits what can be annotated
  - More recent reports are better specified – demonstrates the value added by reporting guidelines (e.g. TIDiER, Hoffman et al, 2014); CONSORT for non-pharmacological trials, Boutron et al, 2017)
- Poorly reported information in reports
  - Limits ability to classify
  - Renders studies non-comparable with others
- A small minority of pdfs can't be annotated using the software

External stakeholder review

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- **Two over-arching questions:**
  1. Comprehensive coverage?
  2. Priorities for feature extraction?

1. **Comprehensiveness of coverage:**
   - Share sections of the relevant part of the ontology (e.g. for population, may show “socioeconomic factors” section of the ontology)
   - Key questions:
     - Are there any attributes missing in this category?
     - Are there any terms or definitions for which you would suggest changes?
   - Comments on comprehensiveness subjected to thematic analysis by two coders

2. Priorities for feature extraction

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- **Perceived importance** (to inform priority setting) assessed with two tasks
- **Open ended question:**
  - If you were trying the understand the effectiveness of behaviour change interventions, what characteristics of the target populations would you be most interested in?
  - Results subjected to thematic analysis
- **Rating task:**
  - Think of behaviour you're familiar with. How important do you think participants' age/gender is to understanding variation in the effectiveness of behaviour change interventions?
  - Rated from 1 (not important) – 5 (very important)

Share draft of the lower level ontology

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- Upload draft with relevant documentation to Open Science Framework
  - Invite feedback
- Publish paper and ontology on OBO Foundry

Linking with developing Cochrane PICO Ontology

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Cochrane Linked Data

Trusted evidence.
Informed decisions.
Better health.

http://linkeddata.cochrane.org/pico-ontology

PICO ontology

- **P**atient, Population or Problem
  - What are the characteristics of the patient or population (demographics, risk factors, pre-existing conditions, etc)?
  - What is the condition or disease of interest?
- **I**ntervention
  - What is the intervention under consideration for this patient or population?
- **C**omparison
  - What is the alternative to the intervention (e.g. placebo, different drug, surgery)?
- **O**utcome
  - What are the relevant outcomes (e.g. quality of life, change in clinical status, morbidity, adverse effects, complications)?

Michie *et al. Implementation Science* (2017) 12:121
DOI 10.1186/s13012-017-0641-5

Implementation Science

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STUDY PROTOCOL Open Access

CrossMark

The Human Behaviour-Change Project: harnessing the power of artificial intelligence and machine learning for evidence synthesis and interpretation

Read Supplementary Files!

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Questions and discussion

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Slides not used

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The Behaviour Change Intervention (BCI) Knowledge System

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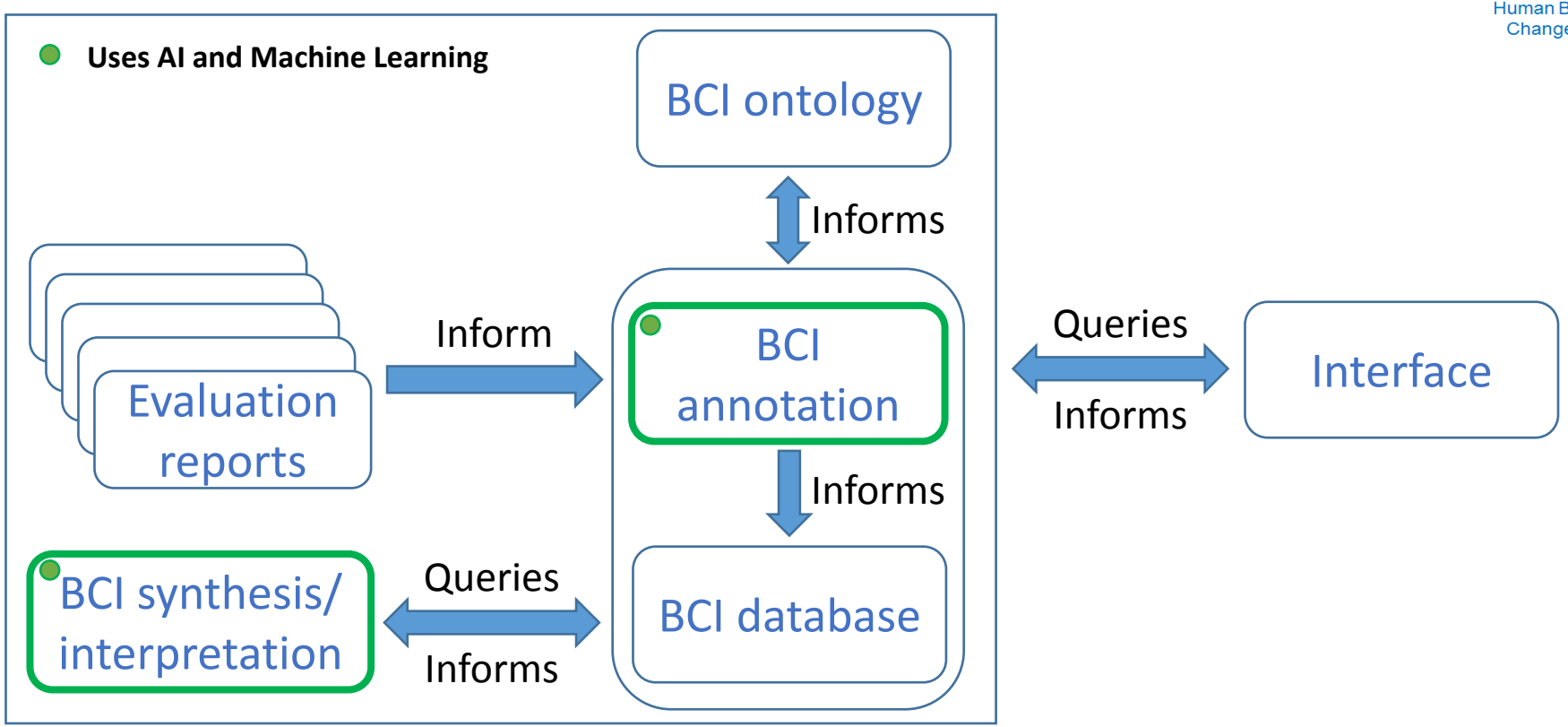
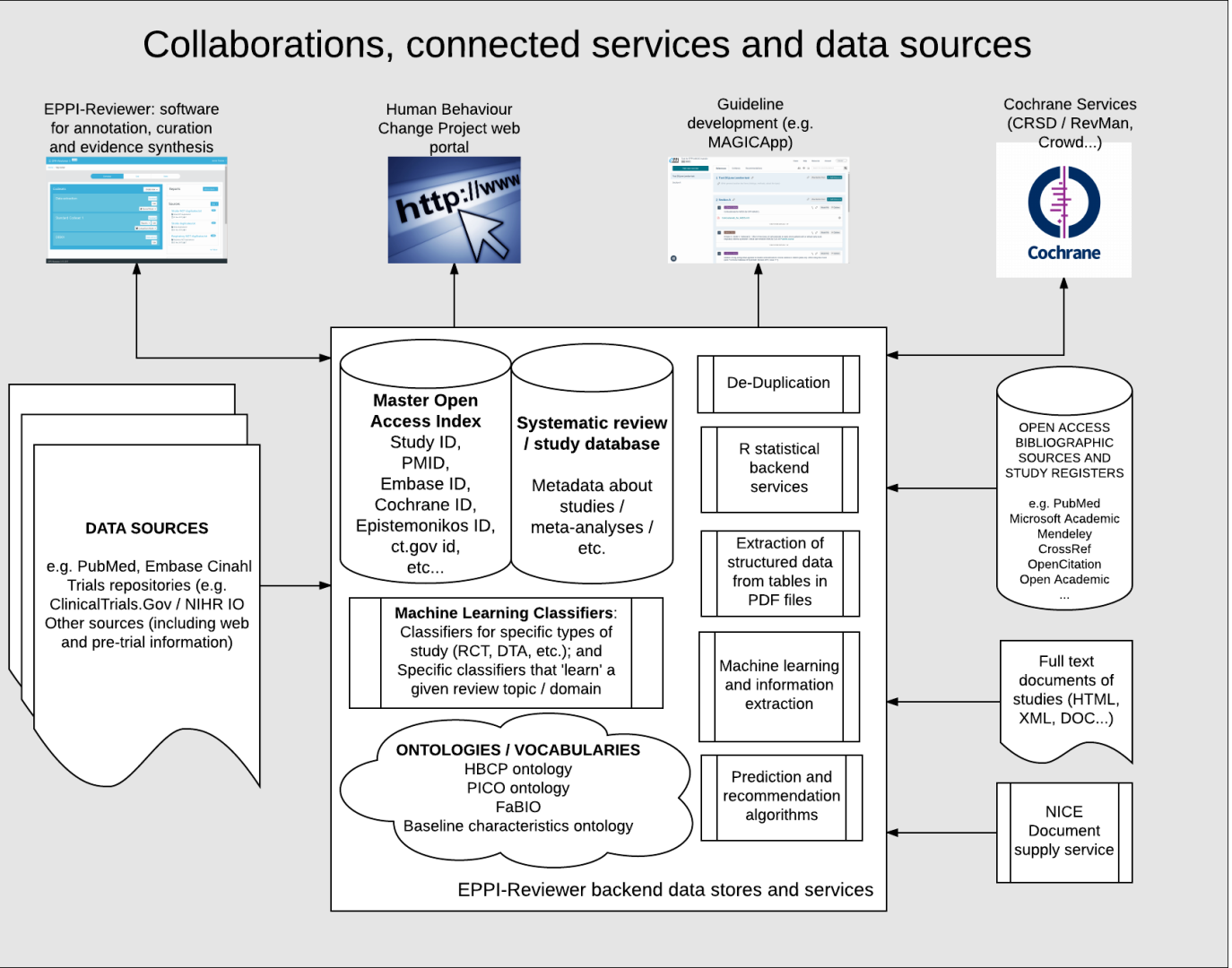


Collaborations, connected services and data sources



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More info from
Prof James Thomas
james.thomas@ucl.ac.uk

The Human Behaviour-Change Project

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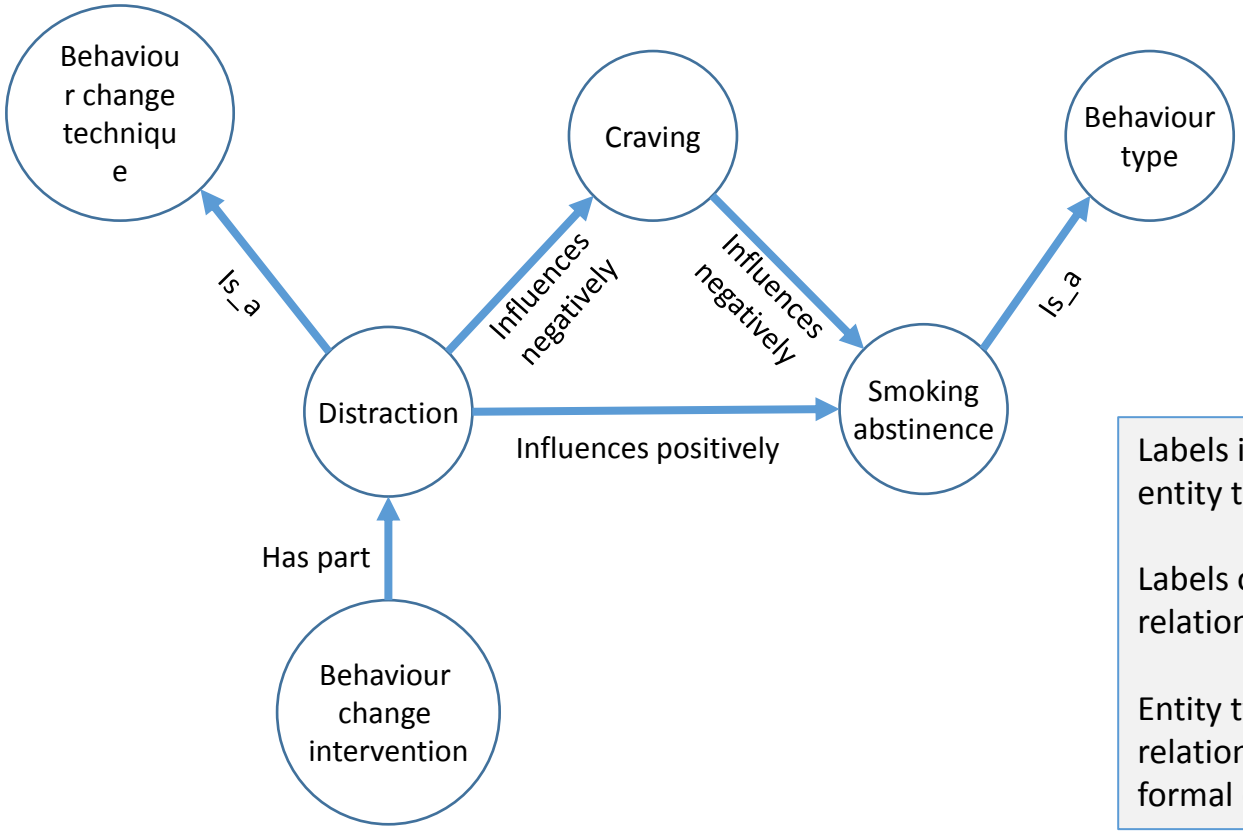
Brings together behavioural science, computer science and information science to create and evaluate a Behaviour Change Intervention (BCI) Knowledge System:

1. An ontology of BCI interventions and evaluation reports
2. A largely automated feature extraction system to read BCI evaluation reports, using Natural Language Processing
3. A BCI database containing information from evaluation reports structured according to the ontology
4. Reasoning and machine learning algorithms to synthesise this information in response to user queries
5. An interface for computers and human users to interact with the system

A mini-ontology



Labels in circles identify entity types

Labels on arrows identify relationship types

Entity types and relationship types require formal definitions

What ontologies can do

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1. Improve clarity of thinking and reporting
2. Generate new ideas and testable hypotheses
3. Identify information gaps and promotes lateral thinking
4. Facilitate interoperability across domains of knowledge and knowledge representations
5. Provide a powerful and intuitive basis for automated querying and reasoning

Desirable qualities

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- Clear definitions for all terms i.e. non-overlapping terms without redundancy
- Well-organised, hierarchical structure
- Comprehensive coverage of the area
- Granularity
  - appropriate to how information represented in evaluation reports and to types of question likely to be asked of the Knowledge System