Revolutionising evidence synthesis and use: the Human Behaviour-Change Project

Susan Michie
Centre for Behaviour Change
University College London, UK

@SusanMichie

German Network for Evidence-based Medicine, 2018
Acknowledgments

• Funders including
  - Medical Research Council (MRC)
  - Economic & Social Research Council (ESRC)
  - Wellcome Trust
  - Cancer Research UK
  - National Institute for Health Research

• The Human Behaviour Change Project

• The Health Psychology Research Team

• The Centre for Behaviour Change
This talk

1. Challenges to increasing the effectiveness of behavioural interventions
   • Reporting interventions
   • Synthesising evidence to generate new insights about behaviour change

2. The Human Behaviour-Change Project
Behaviour change is of critical importance in addressing all of these
Interventions to change behaviour

- We have a rich source of theories and methods for intervention design.
- Considerable investment in interventions aimed at individuals, communities, and populations.
  - Trials: estimated 100's behaviour change interventions per day.
  - Most have modest and variable effects.
  - *e.g. Cochrane database, National Institute for Health & Care Excellence (NICE)*

How can we improve this situation?
Interventions to change behaviour

• If we are to improve interventions, need to
  1. understand reasons for their variation
  2. reduce waste in research (*Lancet* series, 2014)

• This requires
  1. Better reporting of all aspects of interventions and their contexts
  2. The ability to
    1. organise and synthesise large amounts of complex evidence at scale and rapidly
    2. Make inferences from that evidence to generate new understanding
Research: increasing value, reducing waste 5

Reducing waste from incomplete or unusable reports of biomedical research

Paul Glasziou, Douglas G Altman, Patrick Bossuyt, Isabelle Boutron, Mike Clarke, Steven Julious, Susan Michie, David Moher, Elizabeth Wager

- 40–89% interventions non-replicable
- Recommendations include
  - High quality and complete reporting demanded by journals, authors and peer reviewers
    - use reporting guidelines

Glasziou et al, Lancet, 2014
## Reporting behavioural interventions

- vague, partial and/or use terminology inconsistently

<table>
<thead>
<tr>
<th>Title of journal article</th>
<th>Description of “behavioural counseling”</th>
</tr>
</thead>
<tbody>
<tr>
<td>The impact of <em>behavioral counseling</em> on stage of change fat intake, physical activity &amp; cigarette smoking in adults at increased risk of coronary heart disease</td>
<td>“educating patients about the benefits of lifestyle change, encouraging them, and suggesting what changes could be made” (Steptoe et al. <em>AJP</em>H 2001)</td>
</tr>
<tr>
<td>Effects of internet <em>behavioral counseling</em> on weight loss in adults at risk for Type 2 diabetes</td>
<td>“feedback on self-monitoring record, reinforcement, recommendations for change, answers to questions, and general support” (Tate et al. <em>JAMA</em> 2003)</td>
</tr>
</tbody>
</table>
The problem of poor descriptions

- Vague and lacking detail; use of inconsistent and varying terminology
- We need language that is understood by all, with the same terms used for the same things
- Without this, we are limited in our ability to
  - replicate,
  - implement effective interventions,
  - evaluate or
  - improve interventions
Reporting guidelines/ tools helpful

Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide

Behaviour change techniques: the development and evaluation of a taxonomic method and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data)

Susan Michie, Caroline E Wood, Marie Johnston, Charles Abraham, Jill J Francis and Wendy Hardeman

Tammy C Hoffmann associate professor of clinical epidemiology, Paul P Glasziou director and
Reporting intervention content: behaviour change techniques (BCTs)

• “Active ingredients” within an intervention designed to change behaviour

• They are
  • discrete, low-level components of an intervention that on their own have potential to change behaviour
  • observable and replicable

BCT Taxonomy v1

• Developed by 400 experts from 12 countries
• Clearly labelled, well defined, distinct, precise; can be used with confidence by a range of disciplines and countries
• Hierarchically organised to improve ease of use
• Applies to an extensive range of behaviour change interventions

### BCT Taxonomy v1: 93 items in 16 groupings

<table>
<thead>
<tr>
<th>Page</th>
<th>Grouping and BCTs</th>
<th>Page</th>
<th>Grouping and BCTs</th>
<th>Page</th>
<th>Grouping and BCTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1. Goals and planning</td>
<td>8</td>
<td>6. Comparison of behaviour</td>
<td>16</td>
<td>12. Antecedents</td>
</tr>
<tr>
<td></td>
<td>1.1. Goal setting (behavior)</td>
<td></td>
<td>6.1. Demonstration of the behavior</td>
<td></td>
<td>12.1. Restructuring the physical environment</td>
</tr>
<tr>
<td></td>
<td>1.2. Problem solving</td>
<td></td>
<td>6.2. Social comparison</td>
<td></td>
<td>12.2. Restructuring the social environment</td>
</tr>
<tr>
<td></td>
<td>1.3. Goal setting (outcome)</td>
<td></td>
<td>6.3. Information about others’ approval</td>
<td></td>
<td>12.3. Avoidance/reducing exposure to cues for the behavior</td>
</tr>
<tr>
<td></td>
<td>1.4. Action planning</td>
<td></td>
<td></td>
<td></td>
<td>12.4. Distraction</td>
</tr>
<tr>
<td></td>
<td>1.5. Review behavior goal(s)</td>
<td></td>
<td></td>
<td></td>
<td>12.5. Adding objects to the environment</td>
</tr>
<tr>
<td></td>
<td>1.6. Discrepancy between current behavior and goal</td>
<td></td>
<td></td>
<td></td>
<td>12.6. Body changes</td>
</tr>
<tr>
<td></td>
<td>1.7. Review outcome goal(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.8. Behavioral contract</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.9. Commitment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>7. Associations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.1. Prompts/cues</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.2. Cue signalling reward</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.3. Reduce prompts/cues</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### No. | Label | Definition | Examples

1. **Goals and planning**

1.1  **Goal setting (behavior)**

- Set or agree on a goal defined in terms of the behavior to be achieved
- Note: only code goal-setting if there is sufficient evidence that goal set as part of intervention; if goal unspecified or a behavioral outcome, code 1.3, **Goal setting (outcome)**: if the goal defines a specific context, frequency, duration or intensity for the behavior, also code 1.4, **Action planning**

- Agree on a daily walking goal (e.g. 3 miles) with the person and reach agreement about the goal

- Set the goal of eating 5 pieces of fruit per day as specified in public health guidelines
The BCT smartphone app

• Search by BCT label, BCT category or alphabetically

Find by search term: BCTs
Guidelines and taxonomies

• Improve reporting and reduce waste in research
BUT
• on their own do not create new knowledge
The Human Behaviour-Change Project

Participating organisations:
- UCL
- University of Aberdeen
- University of Cambridge
- IBM Research

A Collaborative Award funded by the Wellcome Trust

www.humanbehaviourchange.org
@HBCProject
# The collaboration

<table>
<thead>
<tr>
<th>Grant-holders</th>
<th>Researchers</th>
<th>Computer science</th>
<th>System architecture</th>
</tr>
</thead>
</table>
| Susan Michie\(^1\)  
Marie Johnston\(^3\)  
Robert West\(^1\)  
Mike Kelly\(^4\) | Alison Wright\(^1\)  
Ailbhe Finnerty\(^1\)  
Marta Marques\(^1\)  
Emma Norris\(^1\) | John Shawe-Taylor\(^1\)  
Pol MacAonghusa\(^2\) | James Thomas\(^1\) |
| | Debasis Ganguly\(^2\)  
Lea Deleris\(^2\) | | |

**Project Manager:** Rebecca Jones\(^1\), Leonor Fontoura\(^2\); **Administrator:** Candice Moore\(^1\); **Consultants:** Janna Hastings, Julian Everett, **PhD Students:** Paulina Schenk\(^1\), Anneliese Arno\(^1\), Gaurav Singh\(^1\), Tobias Baumann\(^1\)

\(^1\)UCL  \(^2\)IBM Research Dublin  \(^3\)Aberdeen University  \(^4\)Cambridge University
The Human Behaviour-Change Project: harnessing the power of artificial intelligence and machine learning for evidence synthesis and interpretation

Susan Michie¹, James Thomas², Marie Johnston³, Pol Mac Aonghusa⁴, John Shawe-Taylor⁵, Michael P. Kelly⁶, Léa A. Deleris⁴, Aílbhe N. Finnerty¹, Marta M. Marques¹, Emma Norris¹, Alison O’Mara-Eves² and Robert West⁷
The primary goal of Behavioural Science

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?
<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research conduct:</strong> Diversity of research methods and topics; inconsistency and incompleteness in reporting</td>
<td>Ontology of behaviour change interventions</td>
</tr>
</tbody>
</table>
Challenges and solutions in evidence synthesis

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research conduct:</strong> Diversity of research methods and topics; inconsistency and incompleteness in reporting</td>
<td>Ontology of behaviour change interventions to organise evidence</td>
</tr>
<tr>
<td><strong>Resource limitations:</strong> Insufficient human resources given the increasing volume of research and need for timely knowledge</td>
<td>Use of automated literature searching and study feature extraction</td>
</tr>
</tbody>
</table>
## Challenges and solutions in evidence synthesis

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research conduct:</strong> Diversity of research methods and topics; inconsistency and incompleteness in reporting</td>
<td>Ontology of behaviour change interventions to organise evidence</td>
</tr>
<tr>
<td><strong>Resource limitations:</strong> Insufficient human resources given the increasing volume of research and need for timely knowledge</td>
<td>Use of automated literature searching and study feature extraction</td>
</tr>
<tr>
<td><strong>Research findings:</strong> Equivocal or contradictory findings; sparseness of findings relative to the variety of behaviours, interventions, contexts; complexity of interactions between intervention components, contexts and behaviours</td>
<td>Use of machine learning and reasoning algorithms for evidence synthesis and interpretation to build a Knowledge System</td>
</tr>
</tbody>
</table>
The Human Behaviour-Change Project

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
The Behaviour Change Intervention (BCI) Knowledge System

- Uses AI and Machine Learning

**BCI ontology**

**BCI annotation**

**BCI database**

**Evaluation reports**

**BCI synthesis/interpretation**

**Queries**

**Inform**

**Informs**

**Interface**
Examples of Human Users

Behavioural scientist

E.g. what mechanisms of action are likely to account for the effect of x on y?

Public health policy-maker

E.g. what do I need to do to bring about this change in this population?

The Knowledge System

Detects patterns, makes inferences
Ontology

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’ ...)

A mini-ontology

- Behaviour change technique
- Craving
- Distraction
- Smoking abstinence
- Behaviour type

Labels in circles identify entity types

Labels on arrows identify relationship types

Entity types and relationship types require formal definitions
What ontologies can do

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
Top-level BCI Ontology (BCIO): scenario entities and causal connections
Top level entities in BCIO
Specific ontologies being developed for...

1. Behaviour change techniques – BCTTv1
2. Mode of delivery
3. Exposure of intervention
   • Reach and engagement
4. Target behaviour
5. Target population
6. Intervention setting
7. Mechanisms of action
   • Processes by which change occurs
Desirable qualities

• 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
Domain and scope

• Domain
  • Evaluations of behaviour change interventions

• Scope
  • Initially reports of RCTs of smoking cessation interventions
    • In Cochrane meta-analyses
  • Expanding to RCTs of interventions to change other behaviour types
    • Physical activity, alcohol consumption, dietary behaviours
  • Eventually extend across behaviours and study designs and quality
Building the Knowledge System

Machine Learning
Find optimal connections and weights to classify outputs from input data

Reasoning Algorithms
Using entity relationships and axioms to infer new entity relationships
The algorithms will

- be trained, tested and updated using the BCI database and BCI ontology
- query the BCI database for features specified by the user
- predict effect sizes for BCI Ontology entities that are queried, along with a confidence estimate i.e. a machine generated judgement of the probability that the prediction is correct
- allow explanation of how they arrived at their conclusions and state important caveats
- generate new insights about behaviour change from patterns of associations
Interactive Interface

• Develop and evaluate an online, open-access, interactive interface to enable widespread use of the knowledge generated
  • provide an easy method for searching the literature using purpose-built syntax for fixed and open parameters, level of abstraction etc.
  • bring user feedback from a wide perspective of views into the database, and into the BCI Ontology
  • use by other computer programs
Key resource: addressing problem upstream

- Template for reporting BCIs and BCI evaluations using the BCIO
- To enable
  - clear, full reporting
  - data synthesis
  - interoperability i.e. link to other, related ontologies thus extending knowledge

<table>
<thead>
<tr>
<th>Feature in BCIO</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample_mean_age_yrs</td>
<td>35.4</td>
</tr>
<tr>
<td>Sample_female_%</td>
<td>52.1</td>
</tr>
<tr>
<td>Intervention_brand</td>
<td>ACT</td>
</tr>
<tr>
<td>Intervention_content_BCTs</td>
<td>1,3,12,34,45,60</td>
</tr>
<tr>
<td>Comparator_content_BCTs</td>
<td>1,3,12</td>
</tr>
<tr>
<td>Behavioural_target_type</td>
<td>Smoking cessation</td>
</tr>
<tr>
<td>Outcome_type</td>
<td>Sustained_abstinence</td>
</tr>
<tr>
<td>Setting_clinical_type</td>
<td>GP practice</td>
</tr>
<tr>
<td>Etc.</td>
<td>Etc.</td>
</tr>
</tbody>
</table>
The Human Behaviour-Change Project: harnessing the power of artificial intelligence and machine learning for evidence synthesis and interpretation

Susan Michie¹, James Thomas², Marie Johnston³, Pol Mac Aonghusa⁴, John Shawe-Taylor⁵, Michael P. Kelly⁶, Léa A. Deleris⁴, Aibhe N. Finnerty¹, Marta M. Marques¹, Emma Norris¹, Alison O’Mara-Eves² and Robert West⁷
The Human Behaviour-Change Project

Questions and discussion

www.humanbehaviourchange.org

@HBCProject