RESEARCH ARTICLE

Specifying who delivers behaviour change interventions: development of an Intervention Source Ontology [version 1; peer review: 2 approved, 1 approved with reservations]

Emma Norris¹,², Alison J. Wright², Janna Hastings², Robert West³, Neil Boyt², Susan Michie²

¹Health Behaviour Change Research Group, Brunel University London, Uxbridge, UB8 3PH, UK
²Centre for Behaviour Change, University College London, London, WC1E 7HB, UK
³Research Department of Epidemiology & Public Health, University College London, London, WC1E 7HB, UK

Abstract

Background: Identifying how behaviour change interventions are delivered, including by whom, is key to understanding intervention effectiveness. However, information about who delivers interventions is reported inconsistently in intervention evaluations, limiting communication and knowledge accumulation. This paper reports a method for consistent reporting: The Intervention Source Ontology. This forms one part of the Behaviour Change Intervention Ontology, which aims to cover all aspects of behaviour change interventions.

Methods: The Intervention Source Ontology was developed following methods for ontology development and maintenance used in the Human Behaviour-Change Project, with seven key steps: 1) define the scope of the ontology, 2) identify key entities and develop their preliminary definitions by reviewing existing classification systems (top-down) and reviewing 100 behaviour change intervention reports (bottom-up), 3) refine the ontology by piloting the preliminary ontology on 100 reports, 4) stakeholder review by 34 behavioural science and public health experts, 5) inter-rater reliability testing of annotating intervention reports using the ontology, 6) specify ontological relationships between entities and 7) disseminate and maintain the Intervention Source Ontology.

Results: The Intervention Source Ontology consists of 140 entities. Key areas of the ontology include Occupational Role of Source, Relatedness between Person Source and the Target Population, Sociodemographic attributes and Expertise. Inter-rater reliability was found to be 0.60 for those familiar with the ontology and 0.59 for those unfamiliar with it, levels of agreement considered 'acceptable'.

Conclusions: Information about who delivers behaviour change interventions can be reliably specified using the Intervention Source Ontology. For human-delivered interventions, the ontology can be...
used to classify source characteristics in existing behaviour change reports and enable clearer specification of intervention sources in reporting.

**Keywords**

ontology, behaviour change, intervention delivery, intervention reporting, occupational groups, evidence synthesis

---

**Corresponding authors:** Emma Norris (emma.norris@brunel.ac.uk), Susan Michie (s.michie@ucl.ac.uk)

**Author roles:**

Norris E: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; Wright AJ: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; Hastings J: Methodology, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; West R: Investigation, Methodology, Writing – Review & Editing; Boyt N: Formal Analysis, Investigation, Writing – Review & Editing; Michie S: Conceptualization, Funding Acquisition, Methodology, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing

**Competing interests:** No competing interests were disclosed.

**Grant information:** This work is supported by the Wellcome Trust through a collaborative award to the Human Behaviour-Change Project [201524].

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Copyright:** © 2021 Norris E et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Data associated with the article are available under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original data is properly cited.

**How to cite this article:** Norris E, Wright AJ, Hastings J et al. Specifying who delivers behaviour change interventions: development of an Intervention Source Ontology [version 1; peer review: 2 approved, 1 approved with reservations] Wellcome Open Research 2021, 6:77 https://doi.org/10.12688/wellcomeopenres.16682.1

**First published:** 08 Apr 2021, 6:77 https://doi.org/10.12688/wellcomeopenres.16682.1
**Introduction**

Behaviour change interventions vary greatly in the manner they are delivered. Understanding and reporting the delivery of an intervention is essential to understanding its effectiveness, the mechanisms of change and reasons for variation in effectiveness (Dombrowski et al., 2016). To enable implementation of effective behaviour change interventions and replication of interventions in scientific enquiry, it is essential to provide clear and well-specified reporting of all aspects of interventions, including delivery (Michie et al., 2017; Michie et al., 2020). The delivery of an intervention includes three core components: i) mode of delivery, i.e. how the intervention content is provided to participants such as via a website or face-to-face counselling (Dombrowski et al., 2016; Marques et al., 2020), ii) schedule, i.e. how intervention content is provided to participants over the course of an intervention and iii) source, i.e. who (individually or collectively as a group or organisation) delivers the intervention content (Michie et al., 2021). In this paper, we consider intervention source.

Pre-existing relationships between an intervention’s source and participants may have an impact on intervention effectiveness. For example, peer-based interventions for health behaviours in adults may lead to greater effects than staff-delivered interventions (Cabassa et al., 2017; Weibel et al., 2010). Interventions are often developed to be delivered by a specific source, such as delivery of smoking cessation interventions to patients by nurses (Rice et al., 2017), and their effectiveness may not generalise to delivery by other sources (Glasgow et al., 2003). Those delivering the intervention may require certain levels of knowledge and skills, or to have undergone intervention-specific training.

Guidelines aim to improve the quality of research reporting in terms of consistency, specificity and comprehensiveness. However, the most widely used of these, the CONSORT Standards of Reporting Trials statement (CONSORT; Schulz et al., 2010) and its extension for social and psychology interventions (CONSORT-SPI: Montgomery et al., 2018) do not specify reporting who delivers interventions. The Template for Intervention Description and Replication checklist (TIDieR; Hoffmann et al., 2014) includes one item (Item 5: “Who provided – For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given”) but this is not further elaborated. The reporting of source characteristics within intervention reports using these brief guidelines is often poor. For example, specification of intervention providers was found to be one of four areas requiring improvement in obesity interventions (Rauh et al., 2021). We currently lack a method for specifying characteristics of an intervention’s source within behaviour change interventions.

An appropriate method for specifying and classifying interventions is an ontology: a data structure that enables precise specification of knowledge in a given domain (Arp et al., 2015) (see glossary of italicised terms in Table 1). Ontologies provide a set of: i) unique and unambiguous identifiers representing types of entity (objects, attributes and/or processes), ii) labels and definitions corresponding to these identifiers, and ii) specified relationships between the entities (Arp et al., 2015; Larsen et al., 2017; Norris et al., 2019). These labels, definitions and relationships provide formal specification and a ‘controlled vocabulary’ for the given domain. Ontologies are dynamic representations that are maintained and updated according to new evidence in the given field (Arp et al., 2015; Michie & Johnston, 2017), in fields such as molecular biology (Ashburner et al., 2000). Ontologies are also machine-readable, hence suitable for annotation, evidence synthesis and other computational applications (Hastings, 2017).

No ontology currently exists to describe the full detail of behaviour change intervention sources (Norris et al., 2019). A comprehensive Behaviour Change Intervention Ontology (BCIO) is being developed as part of the Human Behaviour-Change Project (Michie et al., 2017; Michie et al., 2020). The BCIO consists of an upper level with 42 entities, one of which is Behaviour change intervention source, specified as part of the Delivery in a given behaviour change intervention (BCI) scenario (Michie et al., 2021). The current study used the ontology development methodology specified for the Human-Behaviour Change Project (Wright et al., 2020) to develop a reliable ontology for specifying and classifying who delivers interventions. This paper reports the development and final version of the Intervention Source Ontology.

**Methods**

The Intervention Source Ontology was developed in an iterative process of seven steps (Wright et al., 2020).

**Step 1 – Development of the scope and definition of the Intervention Source Ontology**

A definition and overall topic for the ontology was set by reviewing dictionaries and the TIDieR reporting guidelines (Hoffmann et al., 2014)(March 2018).

**Step 2 – Identifying key entities and developing the preliminary Intervention Source Ontology**

An initial prototype version of the ontology was developed using both a bottom-up and top-down approach. In the bottom-up approach, 100 published reports of behaviour change interventions were reviewed to develop an initial list of source characteristics. This number of reports was chosen to generate a good initial range of entities for inclusion in the ontology (Wright et al., 2020). These reports were part of a large dataset of behaviour change intervention reports partially coded for behaviour change techniques, mechanisms of action, and modes of delivery, covering a range of health behaviours (Carey et al., 2019; Michie et al., 2015).

In the top-down approach, existing classification systems related to intervention source characteristics were reviewed, including: i) occupational classification systems (e.g. International Standard Classification of Occupations (ISCO-08; Ganzeboom & Treiman, 1996; International Labour Office, 2012), ii) published ontologies containing terms related to behaviour
| Term                   | Definition                                                                                                                                                                                                 | Source                                                                                      |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| Annotation             | Process of coding selected parts of documents or other resources to identify the presence of ontology entities                                                                                           | Michie et al., 2017.                                                                         |
| Annotation guidance manual | Written guidance on how to identify and tag pieces of text from intervention evaluation reports with specific codes relating to entities in the ontology, using EPPI-Reviewer software. |                                                                                             |
| Basic Formal Ontology (BFO) | An upper level ontology consisting of continuants and occurcents developed to support integration, especially of data obtained through scientific research.                                                   | Arp et al., 2015.                                                                             |
| Continuant             | Entities within an ontology that continue to exist over time, for example, objects and spatial regions.                                                                                                                                                      | Arp et al., 2015.                                                                             |
| Entity                 | Anything that exists, that can be a continuant or an occurrent as defined in the Basic Formal Ontology.                                                                                                                                                     | Arp et al., 2015.                                                                             |
| EPPI-Reviewer          | A web-based software program for managing and analysing data in all types of systematic review (meta-analysis, framework synthesis, thematic synthesis etc. It manages references, stores PDF files and facilitates qualitative and quantitative analyses such as meta-analysis and thematic synthesis. It also has a facilitate to annotate published papers. | Thomas & Brunton, 2010. EPPI-Reviewer 4: http://eppi.ioe.ac.uk/eppireviewer4/ EPPI-Reviewer Web Version: https://eppi.ioe.ac.uk/eppireviewer-web/ |
| GitHub                 | A web-based platform used as a repository for sharing code, allowing version control.                                                                                                                                                                          | https://github.com/                                                                          |
| Inter-rater reliability | Statistical assessment of similarity and dissimilarity of coding between two or more coders. If inter-rater reliability is high this suggests that ontology entity definitions and labels are being interpreted similarly by the coders.          | Gwet, 2014. Handbook of inter-rater reliability: The definitive guide to measuring the extent of agreement among raters. Gaithersburg, Advanced Analytics. |
| Interoperability       | Two systems are interoperable if data coming from each system can be used by the other system. Note: An ontology is interoperable with another ontology if it can be used together with or re-uses parts from the other ontology.                                                                 | http://www.obofoundry.org/principles/fp-010-collaboration.html                              |
| Issue tracker          | An online log for problems identified by users accessing and using an ontology.                                                                                                                                                                            | BCIO Issue Tracker: https://github.com/HumanBehaviourChangeProject/ontologies/ issues        |
| OBO Foundry            | The Open Biological and Biomedical Ontology (OBO) Foundry is a collective of ontology developers that are committed to collaboration and adherence to shared principles. The mission of the OBO Foundry is to develop a family of interoperable ontologies that are both logically well-formed and scientifically accurate. | Smith et al., 2007; www.obofoundry.org/                                                      |
| OBO Foundry principles | Good practice principles of ontology development and maintenance intended as normative for OBO Foundry ontologies. Ontologies submitted to OBO Foundry are evaluated against them.                                                                 | http://www.obofoundry.org/principles/fp-000-summary.html                                   |
| Occurrent              | Entities within an ontology that extend over time, for example, processes.                                                                                                                                                                                  | Arp et al., 2015.                                                                             |
| Term                                           | Definition                                                                                                                                                                                                 | Source                                                                                   |
|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Ontology                                      | A standardised representational framework providing a set of terms for the consistent description (or “annotation” or “tagging”) of data and information across disciplinary and research community boundaries. | Arp et al., 2015.                                                                          |
| Parent class                                  | A class within an ontology that is hierarchically related to one or more child (subsumed) classes such that all members of the child class are also members of the parent class and all properties of the parent class are also properties of the child class. | Arp et al., 2015.                                                                          |
| ROBOT                                         | An automated command line tool for ontology workflows.                                                                                                                                                     | Jackson et al., 2019; http://robot.obolibrary.org                                          |
| URI                                           | A string of characters that unambiguously identifies an ontology or an individual entity within an ontology. Having URI identifiers is one of the OBO Foundry principles. | http://www.obofoundry.org/principles/fp-003-uris.html                                     |
| Versioning                                    | Ontologies that have been released are expected to change over time as they are developed and refined, leading to a series of different files. Consumers of ontologies must be able to specify exactly which ontology files they used to encode their data or build their applications and be able to retrieve unaltered copies of those files in perpetuity. Versioning is one of the OBO Foundry principles. | http://www.obofoundry.org/principles/fp-004-versioning.html                               |
| Web Ontology Language (OWL)                   | A formal language for describing ontologies. It provides methods to model classes of “things”, how they relate to each other and the properties they have. OWL is designed to be interpreted by computer programs and is extensively used in the Semantic Web where rich knowledge about web documents and the relationships between them are represented using OWL syntax. | https://www.w3.org/TR/owl2-quick-reference/                                                 |
change intervention source, via the Ontology Lookup Service and BioPortal, iii) the Patient, Intervention, Comparison, Outcome (‘PICO’) ontology developed by the Cochrane Collaboration due to its relevance for intervention trials; iv) controlled medical vocabularies (e.g. SNOMED CT, MedDRA, MeSH); and v) intervention reporting guidelines such as the Template for Intervention Description and Replication (TiDieR) (Hoffmann et al., 2014)(March – May 2018).

Step 3 – Refining the ontology through literature annotation, discussion and revision

The preliminary ontology was revised by the research team based on annotations of published intervention evaluation reports. Using EPPI-Reviewer 4 software (Thomas & Brutton, 2010), two researchers independently annotated 120 behaviour change intervention evaluation reports using the revised source ontology, with 80 reports on smoking cessation and 40 on physical activity interventions. This number of reports was used as no more additional entities were apparent for inclusion in the ontology (Wright et al., 2020). An open alternative to this software used for annotation is PDFAnno (Shindo et al., 2018). Information on how and when to annotate each source characteristic was provided in an annotation guidance manual to promote standardisation of the procedure. Discrepancies were discussed and the ontology structure, definitions and annotation guidelines were revised accordingly. All reports were randomised controlled trials from one of three datasets: Cochrane reviews, papers annotated for behaviour change techniques and papers already annotated for Behaviour Change Techniques within the iCSmoke systematic review project (Black et al., 2020; de Bruijn et al., 2016)(List of papers used in development of ontology: https://osf.io/6djfk/) (June – October 2018).

Step 4 – Expert stakeholder review

A total of 123 members of an existing international panel of behavioural scientists and public health expert stakeholders at UCL’s Centre for Behaviour Change (Wright et al., 2020) were invited to give feedback on the Intervention Source Ontology resulting from Step 3. These invited experts comprised i) 90 behavioural scientists who had provided feedback on previous projects at the Centre for Behaviour Change, ii) 20 experts from under-represented countries (i.e. not USA, Australis, Canada, UK and Netherlands: the five most commonly represented countries) identified through the BCTTv1 database, and iii) 13 stakeholders who expressed interest in being involved in Human Behaviour-Change Project stakeholder initiatives in response to invitations on Twitter and the project newsletter.

Invitations to participate were sent via email, with feedback collected through an online questionnaire using Qualtrics™ software (full survey is provided as extended data (West et al., 2020)). The task was designed to take no longer than 45 minutes to complete. The task asked experts to:

1. identify the characteristics of an intervention’s source that were of interest to them when trying to understand variation in the effectiveness of behaviour change interventions (open-ended question). Experts were advised to consider a specific behaviour when answering this question e.g. ‘physical activity’.

2. provide feedback on the completeness and comprehensiveness of the Intervention Source Ontology.

Experts were asked to indicate: i) if there were any entities missing (if yes, which should be added), ii) if there were any entities of definitions that should be changed (if yes, what changes should be considered), and iii) if there were any entities that should be placed in a different location in the Intervention Source Ontology.

A thematic analysis of the qualitative responses was done by two researchers (EN & AW), with the larger study team providing feedback on the analysis of the results. Themes were derived directly from responses. Feedback from this expert consultation was discussed by the research team and the Intervention Source Ontology and annotation guidance were revised. Experts did not provide further feedback on these revisions (November 2018 – March 2019).

Step 5 – Inter-rater reliability of annotations using the Intervention Source Ontology

Assessment of inter-rater reliability of the annotations by two researchers leading the development of the ontology was conducted using 50 papers from Cochrane reviews (25 for smoking cessation and 25 for physical activity). This number of papers was selected as 50 papers would give a 10–15% margin of error around the estimated percentage agreement between coders (Gwet, 2014; Wright et al., 2020). Inter-rater reliability was also assessed for annotations by two behaviour change experts unfamiliar with the ontology but with experience in annotating behaviour change intervention reports. Inter-rater reliability with experts unfamiliar with the ontology was performed in two stages: i) a random sample of 50 randomised controlled trials from a database of papers coded by Behaviour Change Techniques, with no restrictions on the outcome behaviour, with revisions to the ontology made accordingly, ii) another random sample of 30 randomised controlled trials with no restrictions on the outcome behaviour from the same database. Inter-rater reliability was assessed using Krippendorff’s Alpha (Hayes & Krippendorff, 2007) calculated using version 1.0.0 of the Automation Inter-Rater Reliability script developed by the HBCP (Finnerty & Moore, 2020), incorporating the python script krippendorff 0.3.2 (April 2019 – January 2021).

Step 6 – Specifying relationships between Intervention Source Ontology entities

The research team established relationships between ontology entities to formalise the knowledge present in the ontology. This process was conducted in line with Basic Formal Ontology principles which have been used extensively in biomedical ontologies (Arp et al., 2015). The suitability of common relationships from Basic Formal Ontology (Arp et al., 2015), the Relation Ontology (Smith et al., 2005) and the Information Artifact Ontology (Ceusters, 2012) were assessed, including the basic hierarchical relationship ‘is a’ which holds between classes where one class is a subclass of another and ‘is about’ which holds between a class representing an information-containing entity and the class that represents what the information is about (January 2021).
Step 7 – Disseminating and maintaining the Intervention Source Ontology

The Intervention Source Ontology was initially developed as a table of entities, with separate rows for each entity annotated with a primary label, definition, synonyms, examples and relationships. When the Intervention Source Ontology was at a stable level of development for initial release, it was converted into Web Ontology Language (OWL) (Antoniou & Van Harmelen, 2004) format, enabling it to be viewed and visualised using ontology software such as Protégé and to be compatible with other ontologies. The conversion to OWL used the ROBOT ontology toolkit library (Jackson et al., 2019), which provides a facility to create well-structured ontologies from templates. A ROBOT template is a comma-separated values (CSV) file that can be prepared easily in common spreadsheet software, annotated with instructions for translation from spreadsheet columns to OWL language and metadata attributes. Within the input template spreadsheet, separate columns represent the entity ID (e.g. BCIO:01023), name, definition, relationship with other entities, examples and synonyms.

This OWL version of the Intervention Source Ontology was then stored on the project GitHub repository, as GitHub has an issue tracker which allows feedback to be submitted by members of the community and can be addressed in subsequent releases. The Intervention Source Ontology was also made available as part of the growing Behaviour Change Intervention Ontology within the Ontology Lookup Service (Côté et al., 2006; Jupp et al., 2015)(February 2021).

Results

Step 1 - Defining the scope of the Intervention Source Ontology

An intervention’s source was defined as ‘A role played by a person, population or organisation that provides a behaviour change intervention’. A ‘role’ in Basic Formal Ontology (BFO) is a type of attribute that is “externally grounded”, that is, it depends on the context or situation of an entity.

Step 2 - Identifying key entities and developing the preliminary Intervention Source Ontology

The International Standard Classification of Occupations (- 08 version) (ISCO-08; International Labour Office, 2012) was identified as a relevant classification system for describing sources’ occupational roles. ISCO-08 is a four-level hierarchically structured classification that allows all occupations internationally to be classified into 436-unit groups. The classification gives job content (tasks and duties) priority over national education and training requirements. Therefore, occupations that involve broadly the same sets of tasks and duties are grouped in the same category in ISCO-08, even where national skill level requirements, measured in terms of formal education, are different.

In assessing the suitability of ISCO to classify occupational roles within the ontology, some minor modifications were made to comply with ontology development guidance regarding specifying entities and reducing redundancy of terms (Grimm & Wissman, 2011). Firstly, ISCO lower-level categories representing duplicate occupations were removed to prevent repetition within the ontology. For example, Other Clerical Support Workers (ISCO: 44) has only one sub-level, Other Clerical Support Workers (ISCO: 441) and so the sub-level was removed to prevent repetition. Second, ISCO occupation categories not found to apply to intervention sources in the bottom-up review of published intervention evaluation reports were removed. Non-relevant ISCO areas were capped at the second level of the ISCO hierarchy to prevent redundant entities being included in the ontology. For example, within Managers (ISCO: 1), entities were capped at the second level (e.g Chief Executives, Senior Officials and Legislators: ISCO: 11) and did not progress to further sub-levels. Managers were not found in development work to actually deliver interventions, although they may oversee other colleagues doing so. In contrast, for health professionals, the bottom-up review of intervention reports suggested that detail represented by all four levels of the ISCO hierarchy would be relevant.

The preliminary version 0.1 ontology of the Intervention Source Ontology encompassed a 5-level hierarchical structure, containing 190 unique entities (https://osf.io/bxsgrd/). 181 of these entities were within the lower-level of Source representing an individual Source’s occupational role. 179 of Person source entities were from ISCO, such as Nursing Professionals (ISCO: 2221), Secondary Education Teachers (ISCO: 233) and Psychologists (ISCO: 2634), with the remaining two entities of Lay Health Worker and Researcher not otherwise specified added to reflect Source occupations found in intervention evaluation reports. The remaining 9 entities were within the lower levels of Expertise of Source including specification of the Source’s training and skills, Source’s role dedicated to intervention specifying whether Source delivered the intervention as part of their usual occupational role or not, and Reimbursement or other incentives given to Source for delivering the intervention.

Step 3 – Refinement of the Intervention Source Ontology

Annotations of published intervention evaluations resulted in changes being made to the Source ontology.

Entities removed from version 0.1 to version 0.2 of ontology: Lower-levels related to occupational roles not identified as being candidate intervention sources were removed to reduce the size of the ontology, such as Travel Attendants, Conductors and Guides, Street & Market Salespersons and Other Sales Workers.

Entities added from version 0.1 to version 0.2 of ontology: Firstly, Person source was expanded to include Student or trainee and lower-levels related to this, reflecting the Source may be an individual currently studying for a qualification. Second, entities to describe Sociodemographics of Source were added to reflect descriptive attributes of the Source reported, such as age, gender and ethnicity. Such characteristics may be reported to characterise the Source, or may reflect selection criteria for Source, e.g recruiting sources of the same gender or from the same ethnic group as the target population. Thirdly, Relatedness between Source and the target population was added, with
entities to describe Payment model of Source were added, with lower-levels reflecting whether the Source was rewarded in a monetary or non-monetary manner for delivering the intervention, or whether the intervention was delivered on a voluntary basis. Last, Organisation Source as a general higher-level term was added to reflect interventions that are delivered by an organisation rather than by a Person Source (individual). For example, a Stop Smoking mass media campaign in England, such as ‘NHS Smokefree’, is delivered by the National Health Service (NHS) nationally (Organisation Source), whilst components are also delivered by individual staff members at local levels (Person Source).

Version 0.2 of the Intervention Source Ontology as a result of these refinements had a 6-level hierarchical structure, containing 186 unique entities (https://osf.io/7zved/).

Step 4 – Expert stakeholder review
Of the 123 experts contacted, 103 were from ‘more-represented’ countries and 20 from ‘less-represented’ countries. Of the 34 experts that responded, 85.3% (29/34) completed the survey, with 27 from ‘well-represented’ and 7 from ‘less-represented’ countries. Experts’ responses and how these were addressed within the ontology development are reported at https://osf.io/58kjt/ (West et al., 2020).

Entities added from version 0.2 to version 0.3 of ontology following expert stakeholder review: First, entities to capture physical and health characteristics of Source were added, including ‘Source Health status’ e.g. body mass index (BMI), body shape, appearance and ‘Source Target Behaviour’ e.g. Source’s smoking status or physical activity level. Second, experts requested elaboration of definition for the ISCO entity ‘Psychologist’ to include a broader range of psychology areas including counselling, forensic, health and neuropsychology. Also, an entity ‘Source involved in co-production of intervention’ was added to reflect where those delivering the intervention were involved in its development.

Version 0.3 of the Intervention Source Ontology as a result of these expert stakeholder recommendations had a 6-level hierarchical structure, containing 196 unique entities (https://osf.io/zfn25/).

Step 5 – Inter-rater reliability of annotations using the Intervention Source Ontology
Inter-rater reliability from the 50 papers annotated by the two researchers familiar with the ontology was found to be ‘acceptable’ (α=0.60; https://osf.io/m3869/) (Hayes & Krippendorff, 2007). The random selection of 50 papers used for inter-rater reliability testing in those unfamiliar with the ontology resulted in papers with the following target behaviours: physical activity (k=19), alcohol (k=7), sexual behaviours (k=6), dietary behaviours (k=5), medication adherence (k=3) and other behaviours such as smoking, hand hygiene and screening (k=10). The inter-rater reliability for these annotations was ‘acceptable’ (α=0.59; https://osf.io/swc57/).

Entities removed from version 0.3 to version 1 of ontology following inter-rater reliability testing: Annotators unfamiliar with the ontology suggested that the v0.3 196-entity ontology could be shortened to improve usability. First, ISCO areas less relevant to describing Intervention Source were capped at their top-level. For example, the lower-levels of ‘Managers’ (ISCO: 1) were removed, such as ‘Chief Executives, Senior Officials and Legislators’ (ISCO: 11) and lower-levels of ‘Clerical Support Worker’ (ISCO: 4) were removed, such as ‘General and Keyboard Clerk’ (ISCO: 41), as not being involved in intervention delivery.

Annotators unfamiliar with the ontology annotated another random sample of 30 randomised controlled trials from the same database with the following target behaviours: physical activity (k=15), sexual behaviours (k=5), alcohol (k=4) and other behaviours such as diet, smoking and tooth brushing (k=6). The inter-rater reliability for these annotations was ‘acceptable’ (α=0.57; https://osf.io/s4g5y/). Version 1 of the Intervention Source Ontology as a result of these annotator recommendations contains 140 unique entities (Table 2).

Step 6 – Specifying the relationships between Intervention Source Ontology entities
Relationships from the Relation Ontology (Smith et al., 2005) were used to connect classes, namely the basic hierarchical relationship ‘is_a’ which holds between classes where one class is a subclass of another class (e.g Medical doctor is_a Health professional), ‘has_role’ which connects a role bearer to a role it holds (e.g Person has_role Person source role), and ‘has_participant’ where one class is involved in the process of another class (e.g Supervision of person source has_participant Person source). The relationship ‘is_about’ from the Information Artifact Ontology (Ceusters, 2012) was also used to represent one class presenting information about another (e.g Total number of people able to deliver intervention is_about Source).

Step 7 - Making the Intervention Source Ontology machine-readable and available online
A downloadable version of the final Intervention Source Ontology is available from GitHub (Norris et al., 2021). The hierarchical structure, URIs, labels and definitions for all entities are described in Table 2. The ontology is accompanied by an annotation guidance manual that provides guidance on how to annotate for these entities in BCI reports (available at https://osf.io/e6dzm/).

Discussion
This study developed the Intervention Source Ontology (Hastings et al., 2021) to specify the characteristics of who delivers behaviour change interventions, as part of the Behaviour Change Intervention Ontology (Michie et al., 2017; Michie et al., 2020). The ontology consists of 140 entities across key areas of Occupational Role of Source, Relatedness between Person Source and the Target Population, Sociodemographic attributes and Expertise. Inter-rater reliability was found to be acceptable for those familiar and unfamiliar with the ontology, as assessed by Krippendorff’s alpha (α=0.60 and 0.59).
Table 2. Entity labels, definitions and examples for all Intervention Source Entities.

| Name                        | Parent class                  | Definition                                                                                                                                                                                                 | Examples                                                                                                                                     |
|-----------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| BCI source [BCIO:010000]    | role [BFO_0000023]           | A role played by a person, population or organisation that provides a BCI.                                                                                                                                   |                                                                                                                                               |
| person [MF:0000016]         | extended organism             | A member of the species Homo Sapiens.                                                                                                                                                                       |                                                                                                                                               |
| person source role [BCIO:010001] | BCI source                | A behaviour change intervention source role that inheres in a person.                                                                                                                                     |                                                                                                                                               |
| person source [BCIO:010002] | person                       | A person who is the bearer of a behaviour change intervention source role.                                                                                                                                   |                                                                                                                                               |
| personal role of source [BCIO:010003] | role                        | A role that inheres in a person source.                                                                                                                                                                    |                                                                                                                                               |
| occupational role of source [BCIO:010004] | personal role of source | A personal role of source that is realised by doing a specified type of work or working in a specified way.                                                                                               | Interventionist, facilitator, study staff                                                                                                     |
| manager [BCIO:010005]       | occupational role of source   | An occupational role of source that manages, plans and coordinates the overall activities of enterprises, governments and other organisations.                                                             | Chief Executive Officers; Administrative Managers; Commercial Managers                                                                      |
| professional [BCIO:010006]  | occupational role of source   | An occupational role that works in knowledge building activities, applies scientific or artistic concepts and theories or teaches about the foregoing in a systematic manner. |                                                                                                                                               |
| science and engineering professional [BCIO:010007] | professional                  | A professional that conducts research, improves or develops concepts, theories and operational methods or applies scientific knowledge.                                                                   | Science Professional, Mathematician, Actuary, Statistician, Life Science Professional, Engineering Professional, Electrotechnology Engineer, Architect, Planner, Surveyor, Designer |
| health professional [BCIO:010008] | professional                  | A professional that improves or develops concepts, theories and operational method, and applied scientific knowledge relating to medicine, nursing, dentistry, veterinary medicine, pharmacy, and promotion of health. | Health professional, Arts therapist, Chiropractor, Dance and movement therapist, Occupational therapist, Osteopath, Podiatrist, Recreational therapist, Health staff, Clinic staff |
| medical doctor [BCIO:010009] | health professional           | A health professional that studies, diagnoses, treats and prevents illness, disease, injury and other physical and mental impairments in humans through the application of modern medicine. They plan, supervise and evaluate the implementation of care and treatment plans by other health care providers, and conduct medical education and research activities. | District medical doctor-therapist, family medical practitioner, general practitioner, medical doctor (general), medical officer (general), physician (general), primary health care physician, resident medical officer specializing in general practice |
| generalist medical practitioner [BCIO:010010] | medical doctor               | A medical doctor that diagnoses, treats and prevents illness, disease, injury and other physical and mental impairments and maintains general health in humans through application of modern medicine. They do not limit their practice to certain disease categories or methods of treatment, and may assume responsibility for the provision of continuing and comprehensive medical care to individuals, families and communities. | Primary care physician, family doctor, GP |
| Name | Parent class | Definition | Examples |
|------|--------------|------------|----------|
| medical doctor | health professional | A medical doctor that diagnoses, treats and prevents illness, disease, injury and other physical and mental impairments in humans, and applies the principles and procedures of modern medicine. They provide and evaluate the care of patients, including the supervision of other health care workers, working autonomously or in teams with medical doctors and others in the practical application of preventive and curative measures. | Anaesthesiologist, Cardiologist, Emergency medicine specialist, Gynaecologist, Obstetrician, Geriatrician, Neonatologist, Oncologist, Radiologist, specialist medical practitioner (public health), specialist medical practitioner (nuclear medicine), Surgeon. |
| health professional | medical doctor | A health professional that provides treatment and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They plan, manage, provide and evaluate midwifery care services before, during and after pregnancy and childbirth. They promote health and well-being for women and newborn children, working autonomously or in teams with other health care providers. | Midwife. |
| health professional | health professional | A health professional that plans, manages, provides and evaluates nursing care services for people who are in need of nursing care due to the effects of ageing, illness or other physical or mental impairments, or potential risks to health. | Clinical nurse consultant, District nurse, Nurse anaesthetist, Nurse educator, Nurse practitioner, Operating theatre nurse, Practice nurse, Public health nurse, Specialist nurse, Nursing Counsellor, Study Nurse. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| health professional | health professional | A health professional that provides treatment, support and care services for people who are physically or mentally ill, disabled or infirm, and those with potential risks to health. They use scientific and technical knowledge to enhance patients' health, offering therapeutic care and support for rehabilitation. | Health promotion officer, Physiotherapist, Occupational therapist, Social worker, Speech pathologist, Therapist. |
| Name                                                      | Parent class | Definition                                                                                                                                                                                                 | Examples                                                                                           |
|----------------------------------------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| pharmacist [BCIO:010019]                                  | health       | A health professional that stores, preserves, compounds and dispenses medicinal products and counsel on the proper use and adverse effects of drugs and medicines following prescriptions issued by medical doctors and other health professionals. | Dispensing chemist, Hospital pharmacist, Industrial pharmacist                                    |
| environmental and occupational health and hygiene professional [BCIO:010020] | health       | A health professional that assesses, plans and implements programmes to recognize, monitor and control environmental factors that can potentially affect human health, to ensure safe and healthy working conditions and to prevent disease or injury caused by chemical, physical, radiological and biological agents or ergonomic factors. | Environmental health officer, Occupational health and safety adviser, Occupational hygienist, Radiation protection expert |
| physiotherapist [BCIO:010021]                             | health       | A health professional that assesses, plans and implements rehabilitative programmes that improve or restore human motor functions, maximize movement ability, relieve pain syndromes, and treat or prevent physical challenges associated with injuries, diseases and other impairments. | Geriatric physical therapist, Manipulative therapist, Orthopaedic physical therapist, Paediatric physical therapist, Physical therapist, Physiotherapist |
| dietician and nutritionist [BCIO:010022]                  | health       | A health professional that assesses, plans and implements programmes to enhance the impact of food and nutrition on human health.                                                                        | Clinical dietician, Food service dietician, Nutritionist, Public health nutritionist, Sports nutritionist |
| audiologist and speech therapist [BCIO:010023]            | health       | A health professional that evaluates, manages and treats physical disorders affecting human hearing, speech, communication and swallowing.                                                                | Audiologist, Language therapist, Speech pathologist, Speech therapist                             |
| optometrist and ophthalmic optician [BCIO:010024]         | health       | A health professional that provides diagnosis, management and treatment services for disorders of the eyes and visual system.                                                                               | Ophthalmic optician, Optometrist, Orthoptist                                                    |
| teaching professional [BCIO:010025]                       | professional | A professional that teaches the theory and practice of one or more disciplines at different educational levels.                                                                                          | Education Methods Specialist, Other Language Teacher, Information Technology Teacher, Private Tutor, School Counsellor, Student Advisor |
| university and higher education teacher [BCIO:010026]     | teaching     | A teaching professional that prepares and delivers lectures and conduct tutorials in one or more subjects within a prescribed course of study at a university or other higher educational institution. They conduct research, and prepare scholarly papers and books. | Higher education lecturer, Professor, University lecturer, University tutor                       |
| vocational education teacher [BCIO:010027]                | teaching     | A teaching professional that teaches or instructs vocational or occupational subjects in adult and further education institutions and to senior students in secondary schools and colleges.                                | Automotive technology instructor, Cosmetology instructor, Vocational education teacher            |
| secondary education teacher [BCIO:010028]                 | teaching     | A teaching professional that teaches one or more subjects at secondary education level.                                                                                                                   | Secondary school teacher, High school teacher                                                    |
| primary school teacher [BCIO:010029]                     | teaching     | A teaching professional that teaches teach a range of subjects at the primary education level.                                                                                                            |                                                                                                   |
| early childhood educator [BCIO:010030]                    | teaching     | A teaching professional that promotes the social, physical, and intellectual development of children below primary school age through the provision of educational and play activities. | Early childhood educator, Pre-school teacher                                                     |
| Name                                | Parent class                        | Definition                                                                                                                                                                                                                                                                                                                                 | Examples                                                                                                                                                                                                                                                                                                                                 |
|------------------------------------|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| special needs teacher              | teaching professional                | A teaching professional that teaches children, young persons or adults with physical or intellectual special needs.                                                                                                                                                                                                                       | Learning disabilities special education teacher, Learning support teacher, Remedial teacher, Teacher of the hearing impaired, Teacher of the sight impaired, Teacher of gifted children, Teacher of the hearing impaired, Special education teacher.                                                                                                                             |
| music teacher                      | teaching professional                | A teaching professional that teaches students in the practice, theory and performance of music in private or small group tuition or within mainsteam educational institutions.                                                                                                                                                                                                                       | Guitar teacher (private tuition), Piano teacher (private tuition), Violin teacher (private tuition), Saxophone teacher (private tuition), Trumpet teacher (private tuition), Recorder teacher (private tuition), Cello teacher (private tuition).                                                                                                       |
| arts teacher                       | teaching professional                | A teaching professional that teaches students in the practice, theory and performance of dance, drama, visual and other arts (excluding music) in private or small group tuition or within mainsteam educational institutions.                                                                                                                                                                                                                   | Dance teacher (private tuition), Drama teacher (private tuition), Painting teacher (private tuition), Sculpture teacher (private tuition), Ceramics teacher (private tuition), Acting teacher (private tuition).                                                                                                              |
| legal, social and cultural professional | legal, social and cultural professional | A professional that conducts research, improves or develops concepts, theories and operational methods, or applies knowledge relating to the law, social or cultural studies.                                                                                                                                                                                                                     | Lawyer, Judge, Coroner, Librarian, Archivist, Curator, Historian, Political Scientist, Economist, Sociologist, Anthropologist, Philosopher.                                                                                           |
| legal professional                  | legal, social and cultural professional | A legal, social and cultural professional that conducts research on legal problems, advises clients on legal aspects of problems, pleads cases or conducts prosecutions in courts of law and draft laws and regulations.                                                                                                                                                | Lawyer, Judge, Coroner, Librarian, Archivist, Curator, Historian, Political Scientist, Economist, Sociologist, Anthropologist, Philosopher.                                                                                           |
| librarian, archivist and curator    | legal, social and cultural professional | A legal, social and cultural professional that develops and maintains collections of archives, libraries, museums, art galleries and similar establishments.                                                                                                                                                                                                                          | Librarian, Archivist, Curator, Historian, Political Scientist, Economist, Sociologist, Anthropologist, Philosopher.                                                                                           |
| psychologist                       | social professional                 | A social professional that studies the mental processes and behaviour of human beings as individuals or in groups, and applies this knowledge to promote personal, social, educational or occupational adjustment and development.                                                                                                 | Clinical psychologist, Counselling psychologist, Forensic psychologist, Educational psychologist, Forensic psychologist, Neuropsychologist, Speech pathologist, Social worker.                                                                 |
| social work and counselling        | social professional                 | A social professional that provides advice and guidance to individuals, families, groups, communities and organizations in response to social and personal difficulties. They assist clients to develop skills and access resources and support services needed to respond to issues arising from unemployment, poverty, disability, addiction, criminal and delinquent behaviour, marital and other problems. | Counsellor, Addictions counselor, Bereavement counselor, Cardinal, Social work officer, Probation officer, Social worker, Women's welfare organizer. |
| religious professional             | legal, social and cultural professional | A legal, social and cultural professional that functions as a perpetuator of sacred traditions, practices and beliefs. They conduct religious faith or denomination, provide spiritual and moral guidance and perform other functions associated with the practice of a religion.                                                                                      | Bonze, Imam, Minister of religion, Poojari, Priest, Rabbi.                                                                                      |
| Name | Parent class | Definition | Examples |
|------|--------------|------------|----------|
| **author and journalist**<sup>[BCIO:010042]</sup> | legal, social and cultural professional | A legal, social and cultural professional that conceives and creates literary works, and interprets and communicates news and public affairs through the media. | Author, Writer, Journalist, Translator, News anchor |
| **linguist**<sup>[BCIO:010043]</sup> | legal, social and cultural professional | A legal, social and cultural professional that translates or interprets from one language into another. | Visual artist, Musician, Singer, Composer, Dancer, Choreographer, Director, Producer, Actor, Announcer |
| **creative and performing artist**<sup>[BCIO:010044]</sup> | legal, social and cultural professional | A legal, social and cultural professional that communicates ideas, impressions and facts in a wide range of media to achieve particular effects, interprets a composition, or directs the performance of others. | Veterinary Technician |
| **technician and associate professional**<sup>[BCIO:010045]</sup> | professional | A technical and associate professional that performs technical and related tasks connected with the application of scientific or artistic concepts and operational methods or government business regulations. | Medical imaging and therapeutic equipment technician, Pharmaceutical technician, Medical and dental prosthetic technician |
| **health associate professional**<sup>[BCIO:010046]</sup> | health associate professional | A health associate professional that performs technical tasks to support diagnosis and treatment of illness, disease, injuries and impairments. | Practitioner, Out Smoking Counsellor, Health educator, Dispensing optician, Information technician |
| **nursing and midwifery associate professional**<sup>[BCIO:010047]</sup> | medical and pharmaceutical technician | A nursing and midwifery associate professional that performs technical tasks to support diagnosis and treatment of illness, disease, injuries and impairments. | Veterinary Technician |
| **midwifery associate professional**<sup>[BCIO:010048]</sup> | nursing and midwifery associate professional | A midwifery associate professional that performs legal, social and cultural professional | Veterinary Technician |
| **midwifery associate professional**<sup>[BCIO:010049]</sup> | traditional and complementary medicine associate professional | A traditional and complementary medicine associate professional that provides medical, nursing and other health professionals. | Assistant nurse, Associate professional nurse, Enrolled nurse, Practical nurse |
| **traditional and complementary medicine associate professional**<sup>[BCIO:010050]</sup> | traditional and complementary medicine associate professional | A traditional and complementary medicine associate professional that provides medical, nursing and other health professionals. | Assistant midwife, Traditional midwife |

*BCIO:010041* Legal, social and cultural professional

*BCIO:010042* Linguist

*BCIO:010043* Creative and performing artist

*BCIO:010044* Technician and associate professional

*BCIO:010045* Health associate professional

*BCIO:010046* Nursing and midwifery associate professional

*BCIO:010047* Midwifery associate professional

*BCIO:010048* Traditional and complementary medicine associate professional

*BCIO:010049* Traditional and complementary medicine associate professional

*BCIO:010050* Traditional and complementary medicine associate professional
| Name | Parent class | Definition |
|------|--------------|------------|
| Dental assistant | Health associate professional | A health associate professional that provides basic dental care services for the prevention and treatment of diseases and disorders of the teeth and mouth according to care plans and procedures established by a dentist or other oral health professional. Examples: Dental assistant, Dental hygienist, Dental therapist. |
| Community health worker | Health associate professional | A health associate professional that provides health education, referral, and follow-up care management, basic preventive health care and assistance to individuals and families in navigating the health and social services system. Examples: Community health aide, Community health promoter, Community health worker, Village health worker. |
| Acupressure therapist | Health associate professional | A health associate professional that provides physical therapeutic treatments to patients in circumstances where functional movement is threatened by injury, disease or impairment. Therapies are usually provided according to rehabilitative plans established by a health professional. Examples: Acupressure therapist, Electrotherapist, Massage therapist, Physical therapy technician, Shiatsu therapist. |
| Clinical assistant | Health associate professional | A health associate professional that performs basic clinical and administrative tasks to support patient care under the direct supervision of a medical practitioner or other health professional. Examples: Clinical assistant, Medical assistant, Ophthalmic assistant. |
| Environmental health inspector | Health associate professional | A health associate professional that investigates the implementation of environmental rules and regulations relating to environmental factors that may affect human health, safety in the workplace, and safety of processes for the production of goods and services. They may implement and evaluate programmes to restore or improve safety and sanitary conditions under the supervision of a health professional. Examples: Food sanitation and safety inspector, Health inspector, Occupational health and safety inspector, Sanitarian, Sanitary inspector. |
| Ambulance officer | Health associate professional | A health associate professional that provides emergency health care to patients who are injured, sick, infirm or otherwise physically or mentally impaired prior to and during transport to medical facilities. Examples: Ambulance officer, Ambulance paramedic, Emergency medical technician, Emergency medical technician. |
| Financial and Mathematical assistant professional | Business and administration associate professional | A technician and associate professional that performs mostly technical calculations, human resource development, selling and buying financial instruments, specialized secretarial tasks and enforcing or applying government rules. Examples: Financial and Mathematical assistant professional, Emergency medical technician, Financial and Mathematical assistant professional. |
| Bailiff | Business and administration associate professional | A technician and associate professional that performs support functions in courts of law or in law offices, provides services related to legal matters as insurance contracts, the transferring of property and the granting of loans and other financial transactions, or conduct investigations for clients. Examples: Bailiff, Judge's clerk, Conveyancing clerk, Court clerk, Justice of the peace, Law clerk, Legal assistant, Paralegal, Private detective, Title searcher. |
| Community development worker | Social work associate professional | A technician and associate professional that implements social assistance programmes and community services and assist clients to deal with personal and social problems. Examples: Community development worker, Community services worker, Welfare services worker, Youth services worker. |
| Faith healer | Religious associate professional | A technician and associate professional that provides support to ministers of religion or to a religious community, undertakes religious works, preach and propagate the teachings of a particular religion and endeavours to improve well-being through the power of faith and spiritual advice. Examples: Faith healer, Lay preacher, Monk, Nun.
| Name | Parent class | Definition | Examples |
|------|--------------|------------|----------|
| sport and fitness worker [BCIO:010061] | technician and associate professional | A sport and fitness worker that prepares for and organizes sporting events, promotes participation and standards in sport, organizes and officiates sporting events or provides instruction, training and supervision for various forms of exercise and other recreational activities. | Athlete, Boxer, Coach, Ice hockey player, Rollerblader, Tennis player, Windsurfer |
| athlete and sports player [BCIO:010062] | technician and associate professional | A sport and fitness worker that participates in competitive sporting events. | Footballer, Golfer, Hockey player, Jockey, Poker player, Racing driver, Skier, Tennis player, Wrestler |
| sport and fitness instructor [BCIO:010063] | technician and associate professional | A sport and fitness worker that leads, guides and instructs groups and individuals in recreational, fitness or outdoor adventure activities. | Aerobics instructor, Fitness instructor, Horse riding instructor, Outdoor adventure guide, Personal trainer, Sailing instructor, Underwater diving instructor, Swimming instructor |
| fitness and recreation instructor and leader [BCIO:010064] | technician and associate professional | A sport and fitness worker that leads, guides and instructs groups and individuals in recreational, fitness or outdoor adventure activities. | Babysitter, Child care worker, Creche ayah, Family day care worker, Nanny, Out of school hours care worker |
| personal care worker [BCIO:010071] | personal care worker | A personal care worker that provides care, supervision and assistance for children, patients and elderly, convalescent or disabled persons in institutional and residential settings. | Babysitter, Child care worker, Creche ayah, Family day care worker |
| sales worker [BCIO:010070] | personal care worker | A personal care worker that provides care and supervision for children in non-domestic settings. | Personal carer |

Wellcome Open Research 2021, 6:77 Last updated: 21 NOV 2021
| Name | Parent class | Definition | Examples |
|------|--------------|------------|----------|
| teachers' aide | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Home birth assistant, Home care aide, Nursing aide |
| personal care worker | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Personal care worker, Pre-school assistant, Teacher's assistant |
| personal care worker | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Health care assistant, Personal care worker |
| home-based personal care worker | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in private homes and other independent residential settings. | Home birth assistant, Home care aide, Nursing aide |
| protective services worker | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Firefighter, Police officer, Security guard, Offender manager |
| skilled agricultural, forestry and fishery worker | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Market gardener, Crop grower, Animal Producer, Mixed Crop and Animal Producer, Forestry worker, Subsistence Farmer, Subsistence Forester |
| craft and related trades worker | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Building Trade Worker, Metal Workers, Machinery Operator, Electrician, Electrical Machine Operator, Electrical Equipment Installer and Repairer, Food Processing Worker, Woodworker, Tobacco Product Maker |
| plant and machine operator | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Stationary Plant and Machine Operator, Driver, Mobile Plant Operator |
| assembler | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Stationary Plant and Machine Operator, Driver, Mobile Plant Operator |
| elementary occupation | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Stationary Plant and Machine Operator, Driver, Mobile Plant Operator |
| armed forces occupation | personal care worker | A personal care worker that provides direct personal care and assistance to individuals in a variety of health care settings, working in implementation of established care plans and practices, and under the direct supervision of health professionals or associates. | Stationary Plant and Machine Operator, Driver, Mobile Plant Operator |
| Name | Definition | Examples |
|------|------------|----------|
| researcher | A personal role of source that is revealed in an educational institution or professional training setting. | researcher, research assistant, investigator |
| student or trainee role | A personal role of source that is enrolled in an educational institution or a formal programme of professional training. | student or trainee |
| informal education student or trainee role | A student or trainee that is currently learning in a non-institutional setting. | informal education student or trainee |
| vocational training student or trainee role | A student or trainee that is currently learning at a primary or secondary level in an educational institution or professional training. | vocational training student or trainee |
| academic student or trainee role | A student or trainee that is currently learning the material of a university, college or professional school. | academic student or trainee |
| educational student or trainee role | A student or trainee that is currently studying for an advanced educational programme. | educational student or trainee |
| discipline of current programme of study or training | A specific domain of study undertaken by the bearer of a student or trainee role. | psychology, medicine, hairdressing |
| relatedness between person source and the target population | A relationship between person source and the target population that is realised in some relationship to the characteristics of the intervention participants. | family member, father, stepfather, guardian |
| parent or guardian | A family member that is a mother, father or legal carer of a child. | parent or guardian |
| spouse or partner | A family member that is an individual who is married or in a committed relationship with another individual. | spouse or partner |
| Name                                         | Parent class                  | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Examples                          |
|----------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| sibling relationship [BCIO:010098]           | family member                 | A family member that is a family relationship between two persons with at least one shared parent.                                                                                                                                                                                                                                                                                                                                                                           | brother, sister, step-brother, step-sister |
| child relationship [BCIO:010099]             | family member                 | A family member that is an offspring relationship from a person to their parent.                                                                                                                                                                                                                                                                                                                                                                                             | daughter, son, step-daughter, step-son |
| carer  [BCIO:010100]                         | relatedness between person source and the target population | A relatedness between person source and the target population that is an individual who cares, unpaid, for a friend or family member who, due to illness or disability, requires support in their daily life activities.                                                                                                                                                                                                                                         | carer                             |
| friend  [BCIO:010101]                        | relatedness between person source and the target population | A relatedness between person source and the target population that is a person whom the participant knows, likes and trusts, typically exclusive of sexual or family relations.                                                                                                                                                                                                                                                                                         |                                   |
| colleague  [BCIO:010102]                     | relatedness between person source and the target population | A relatedness between person source and the target population that is a person with whom the participant works in a profession or business.                                                                                                                                                                                                                                                                                                                               |                                   |
| employer  [BCIO:010103]                      | relatedness between person source and the target population | A relatedness between person source and the target population that is a person which hires the services of the participant.                                                                                                                                                                                                                                                                                                                                              |                                   |
| peer  [BCIO:010104]                          | relatedness between person source and the target population | A relatedness between person source and the target population that is described as matched to intervention recipients on the basis of ‘peerness’ – age, social status, gender, shared experience, shared health status etc.                                                                                                                                                                                                                                                                 |                                   |
| embedded in participants’ community [BCIO:010105] | relatedness between person source and the target population | A relatedness between person source and the target population that is a source who is known and working to deliver intervention in own community.                                                                                                                                                                                                                                                                                                                      |                                   |
| number of people delivering intervention to each participant [BCIO:010106] | count data item | A count data item that is the number of providers that an individual participant in the intervention encounters.                                                                                                                                                                                                                                                                                                                                                       |                                   |
| total number of people able to deliver intervention [BCIO:010107] | count data item | A count data item that is the total number of providers that are available and able to deliver the intervention.                                                                                                                                                                                                                                                                                                                                                     |                                   |
| socio demographic attribute of person source [BCIO:010108] | person source | A social or demographic characteristic of a human being who is the bearer of a person source role.                                                                                                                                                                                                                                                                                                                                                                         |                                   |
| age of person source [BCIO:010109]           | socio demographic attribute of person source | A socio-demographic attribute of person source that is a time quality inhering in a bearer by virtue of how long the bearer has existed.                                                                                                                                                                                                                                                                                                                                                                   |                                   |
| gender of person source [BCIO:010110]        | socio demographic attribute of person source | A socio-demographic attribute of person source that is an individual’s perception of having a particular gender, which may or may not correspond with their birth sex.                                                                                                                                                                                                                                                                                                  | gender                            |
| female gender  [BCIO:010111]                 | gender of person source       | A gender of person source that is the cultural gender role of female.                                                                                                                                                                                                                                                                                                                                                                                                      | female, woman                      |
| Name | Parent class | Definition | Examples |
|------|--------------|------------|----------|
| male gender | gender of person source | A gender of person source that is the cultural gender role of male. | male, man |
| other gender | gender of person source | A gender of person source that reports not belonging to the cultural gender role distinctions of either male or female. | non-binary, transexual |
| ethnic group membership of person source | socio demographic attribute of person source | A socio-demographic attribute of person source that is the ethnic group to which an individual identifies as belonging, where an ethnic group is a population whose members have a common heritage that is real or presumed such as common culture, language, religion, behaviour or biological trait. | black, white, Indian, Chinese, Somalian |
| religious group membership of person source | socio demographic attribute of person source | A socio-demographic attribute of person source that is a religious group to which an individual identifies as belonging, where a religious group is a group of people characterised by the practice of a common religion. | Muslim, Christian, Hindu, Sikh, Buddhist, Judaism |
| language proficiency of person source | socio demographic attribute of person source | A socio-demographic attribute of person source that is an individual's ability to speak or perform in the intervention language. | fluent, native |
| health status of person source | socio demographic attribute of person source | A socio-demographic attribute of person source that represents their mental or physical condition. | diabetes, cancer, depression, obesity, overweight |
| target behaviour of person source | socio demographic attribute of person source | A socio-demographic attribute of person source that is their amount or experience of the intervention's target behaviour. | source is highly physically active |
| psychological influence on intervention delivery of person source | socio demographic attribute of person source | A socio-demographic attribute of person source that is their existing psychological attributes related to or potentially affecting the target behaviour. |
| expertise of person source | disposition | A disposition that is an expert skill or knowledge held by the source delivering the behaviour change intervention. | trained (if unclear whether pre-existing or acquired) |
| knowledge or skill | expertise of person source | An expertise of person source that is knowledge or skills held in order to deliver the behaviour change intervention. | Bachelor's degree, certification, accredited, qualified |
| pre-existing knowledge or skill | knowledge or skill | A knowledge or skill that is already possessed by the source which allows them to deliver the behaviour change intervention, including educational level and qualifications. |
| expertise discipline | attribute | An attribute that is a field of knowledge or practice. | psychology, yoga, cognitive behavioural therapy, hypnotism |
| discipline of pre-existing knowledge or skill | expertise discipline | The expertise discipline in which the person source has acquired their pre-existing knowledge and skills. | psychology, yoga, cognitive behavioural therapy, hypnotism |
| acquired knowledge or skill | knowledge or skill | A knowledge or skill that is additional knowledge or skills supplied to the source to allow them to deliver the behaviour change intervention, including educational level and qualifications. |
| Name                                               | Parent class               | Definition                                                                                                                                                                                                                                                                                                                                 | Examples                          |
|---------------------------------------------------|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| amount of experience [BCIO:010126]                 | data item                  | A knowledge or skill that is the duration of experience in related domain held by person source.                                                                                                                                                                                                                                         | full-day, 6 years                  |
| affiliation to a formal group or organisation [BCIO:010127] | pre-existing knowledge or skill | A pre-existing knowledge or skill that is recognised through affiliation to a formal group or organisation.                                                                                                                                                                                                                          | member of British Psychological Society |
| supervision of person source [BCIO:010128]        | process                    | A process in which a person source is formally provided, by an individual with appropriate expertise, with corrective and skill-enhancing feedback, regarding the person source's performance in delivering the intervention.                                                                                                                                  | supervised                          |
| volunteering of person source [BCIO:010129]       | process                    | A process in which a person source delivers the intervention on a voluntary basis without formal compensation.                                                                                                                                                                                                                           | voluntary basis, volunteering      |
| payment of person source [BCIO:010130]            | process                    | A process in which a person source is paid or compensated for delivering the intervention.                                                                                                                                                                                                                                            |                                   |
| monetary payment [BCIO:010131]                    | payment of person source    | A payment of person source that is money, vouchers or valued objects given to the source for delivering the intervention.                                                                                                                                                                                                                   | paid in cash, vouchers             |
| non-monetary payment [BCIO:010132]                | payment of person source    | A payment of person source that is non-monetary compensation given to the source for delivering the intervention.                                                                                                                                                                                                                     | course credit                      |
| source role related to intervention [BCIO:010133] | BCI source                 | A BCI source whose occupational or voluntary role is focused on delivery of the behaviour change intervention.                                                                                                                                                                                                                       |                                   |
| source involved in development of intervention [BCIO:010134] | BCI source                 | A BCI source that is involved in the development of intervention content.                                                                                                                                                                                                                                                                |                                   |
| source involved in co-production of intervention [BCIO:010135] | source involved in development of intervention | A source involved in development of intervention that has developed the intervention content in collaboration with key stakeholders such as patients or community members.                                                                                                                                                                |                                   |
| organisation [OBI:0000245]                        | material entity            | An entity that can bear roles, has members, and has a set of organization rules. Members of organizations are either organizations themselves or individual people. Members can bear specific organization member roles that are determined in the organization rules. The organization rules also determine how decisions are made on behalf of the organization by the organization members. |                                   |
| organisational source role [BCIO:010138]          | BCI source                 | A BCI source role that is borne by an organisation.                                                                                                                                                                                                                                                                                      |                                   |
| organisation source [BCIO:010139]                 | organisation               | An organisation that is the bearer of a behaviour change intervention source role, such as voluntary, public or commercial organisations delivering a behaviour change intervention.                                                                                                                                                       |                                   |

Note: BCIO = Behaviour Change Intervention Ontology; BFO = Basic Formal Ontology; MF = Mental Functioning Ontology; OBI = Ontology of Biomedical Investigations.
This suggests that the Intervention Source Ontology and associated annotating guidance can be applied with acceptable consistency, and provides confidence in the methods developed for creating the Behaviour Change Intervention Ontology (Michie et al., 2017; Wright et al., 2020; https://www.humanbehaviourchange.org/).

Ontologies should be maintained and updated according to new evidence about entities and relationships (Arp et al., 2015; He et al., 2018). The Intervention Source Ontology and all other ontologies within the Human Behaviour-Change Project will be updated according to advances in behavioural science and by online ontology user feedback via GitHub. When the full Behaviour Change Intervention Ontology has been released it will be submitted to the OBO Foundry (Smith et al., 2007).

Strengths and limitations
A strength of this work is the integration of international expert stakeholder feedback in appraising and revising the ontology, a practice which is uncommon in ontology development (Norris et al., 2019). Involving a variety of domain experts provides a range of relevant knowledge and perspectives to test the ontology, a process used successfully in developing other taxonomies and frameworks (e.g. BCTTv1, Michie et al., 2015; Linking BCTs and Mechanisms of Action, Carey et al., 2019; MAGI framework, Borek et al., 2019; TIPPME, Hollands et al., 2017).

A limitation of this work is that there was a preponderance of intervention evaluation reports from high income countries, potentially limiting the ontology’s applicability to interventions in low- and middle-income countries. However, incorporating ISCO-08, an occupational classification system designed to have worldwide relevance (International Labour Office, 2012) should enhance the Source ontology’s global applicability. A second limitation is that intervention reports annotated within the ontology development addressed only two health-related behaviours: smoking cessation and physical activity. This was due to the ontology being developed within the Human Behaviour-Change Project, which is using interventions in these behavioural domains as initial use cases (Michie et al., 2017). However, external inter-rater reliability was performed across diverse behaviours and found to be acceptable. Future application of the ontology to a wider collection of behaviours and contexts will allow it to be extended and improved.

In addition to contributing to the larger Behaviour Change Intervention Ontology, the Intervention Source Ontology provides a stand-alone classification system for describing and reporting source characteristics. It can be used to describe who, individually or organisationally, will deliver or has delivered an intervention and to synthesise evidence across studies.

Conclusion
The Intervention Source Ontology provides a classification system that can be used reliably to specify the characteristics of who delivers interventions. It will contribute to improved research reporting and replication, simplifying the process of evidence synthesis across diverse studies. The ontology can be used in conjunction with machine-readable tools, such as the Artificial Intelligence algorithms contributing to the Knowledge System being developed within the Human Behaviour-Change Project (Michie et al., 2017). The Intervention Source Ontology is intended to act as a basis to be elaborated on in future research, as an ongoing and collaborative process. The ontology will increase understanding of what intervention sources are most effective for given intervention scenarios, varying in target population, behavioural domain, setting and a large number of intervention characteristics.

Data availability
Underlying data
Open Science Framework: Human Behaviour-Change Project. https://doi.org/10.17605/OSF.IO/EFP4X (West et al., 2020)

This project contains the following underlying data:
- Expert feedback on Intervention Source Ontology; Raw feedback received from behavioural science and public health experts; https://osf.io/5qkt/

Extended data
Open Science Framework: Human Behaviour-Change Project. https://doi.org/10.17605/OSF.IO/EFP4X (West et al., 2020)

This project contains the following extended data:
- Papers used in development of the Intervention Source Ontology; Papers used across stages of development of the Intervention Source Ontology, with the systematic reviews that they were identified from; https://osf.io/6djfk/
- Version 0.1 Intervention Source Ontology; Initial prototype version of Intervention Source Ontology; https://osf.io/bxqrd/
- Version 0.2 Intervention Source Ontology; Second version of Intervention Source Ontology after initial annotations; https://osf.io/7zved/
- Version 0.3 Intervention Source Ontology; After expert stakeholder feedback; https://osf.io/2f25/
- Expert feedback survey; Full survey provided to behavioural science and public health experts in review of the Intervention Source Ontology; https://osf.io/5hjcl/
- Internal inter-rater reliability testing: https://osf.io/m3869/
- External inter-rater reliability testing; 1st round: https://osf.io/swc57/
- External inter-rater reliability testing; 2nd round: https://osf.io/sg45y/
- Coding guidelines; Manual for coding using the Intervention Source Ontology: https://osf.io/e6dzm/
This project contains the following extended data:
- An archived version 1 of the Intervention Source Ontology.

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

References

Antoniou G, van Harmelen F. Web Ontology Language: OWL. In: S. S. & S. R. (Eds.), Handbook on Ontologies. International Handbooks on Information Systems. Berlin: Springer, 2004: 67–92.

Ap R, Smith B, Spear AD. Building Ontologies with Basic Formal Ontology. Massachusetts: MIT Press. 2015.

Ashburner M, Ball CA, Blake JA, Botstein D, Butler H, Cherry JM, Davis AP, Dolinski K, Dwight SK, Eppig JT, et al. Gene ontology: tool for the unification of biology. The Gene Ontology Consortium. Nat Genet. 2000; 25(1): 25–29.

Black N, Eisma M, Viechtbauer W, et al. Systematic review and meta-analysis of control groups in smoking cessation trials: Implications for conducting and interpreting systematic reviews. Addiction. 2020.

Borek AJ, Smith JR, Greaves CJ, et al. Developing and applying a framework to understand mechanisms of action in group-based, behaviour change interventions: the MAGI mixed-methods study. Efficacy Mech Eval. 2019; 6(3).

Cabassa LJ, Camacho D, Vélez-Grau CM, et al. Peer-based health interventions for people with serious mental illness: a systematic literature review. J Psychiatr Res. 2017; 84: 80–89.

Carey RN, Connell LE, Johnston M, et al. Behavior change techniques and their mechanisms of action: a synthesis of links described in published intervention literature. Am Behav Med. 2019; 53(3): 693–707.

Ceusters W. An information artifact ontology perspective on data collections and associated representational artifacts. Stud Health Technol Inform. In MIE. 2012; 190: 68–72.

Côté RG, Jones P, Apweiler R, et al. The Ontology Lookup Service, a lightweight cross-platform tool for controlled vocabulary queries. BMC Bioinformatics. 2006; 7(1): 97.

de Bruin M, Viechtbauer W, Eisma MC, et al. Identifying effective behavioural components of Intervention and Comparison group support provided in SMOKing cSSation (IC-SMOKE) interventions: a systematic review protocol. Syst Rev. 2016; 5(1): 77.

Dombrowski SU, O’Carroll RE, Williams B. Form of delivery as a key ‘active ingredient’ in behaviour change interventions. Br J Health Psychol. 2016; 21(4): 733–740.

Finnerty A, Moore C. HumanBehaviourChangeProject/Automation-InterRater-Reliability: Release of HBCP inter-rater reliability code v1.0.0. (Version v1.0.0). Zenodo. 2020. http://www.doi.org/10.5281/zenodo.3838816

Ganea2018 ID: 8.1: 2021.

Ganeboom HBG, Treiman DJ. Internationally Comparable Measures of Occupational Status for the 1988 International Standard Classification of Occupations. Soc Sci Res. 1996; 25(4): 201–239.

Glasgow RE, Lichtenstein E, Marcus AC. Why don’t we see more translation of health promotion research to practice? Rethinking the efficacy-to-effectiveness transition. Am J Public Health. 2003; 93(8): 1261–1267.

Grimm S, Wissman J. Elimination of redundancy in ontologies. ESWC'T1 Proceedings of the 8th extended semantic web conference on The semantic web: research and applications. 2011; 1: 260–274.

Hastings J, emmajnorris, AilbheF. HumanBehaviourChangeProject/ontologies: HumanBehaviourChangeProject/ontologies: Upper-Level, Setting, Mode of Delivery & Source ontologies. http://www.doi.org/10.5281/zenodo.4476603

Hastings J: Primer on ontologies. In The Gene Ontology Handbook. Humana Press, New York, NY, 2017; 3–13.

Hayes AF, Krippendorff K. Answering the Call for a Standard Reliability Measure for Coding Data. Commun Methods Meas. 2007; 1(1): 77–89.

Hollands GJ, Bignardi G, Johnston M, et al. The TIPPME intervention typology for changing environments to change behaviour. Nat Hum Behav. 2019; 8(1): 1261–1267.

Hoffmann TC, Glassiou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. BMJ. 2014; 348: g1687.

Holland JS, Bignardi G, Johnston M, et al. The TIPPME intervention typology for changing environments to change behaviour. Nat Hum Behav. 2017; 1(8): 0140.

Jackson RC, Balhoff JP, Douglass E, et al. ROBOT: a tool for automating ontology workflows. BMC Bioinformatics. 2019; 20(1): 407.

Jupp S, Burdett T, Leroy C, et al. A new Ontology Lookup Service at EMBL-EBI. In SWAT4LS. 2015; 118–119.

Larsen KR, Michie S, Hekler EB, et al. Behavior change interventions: the potential of ontologies for advancing science and practice. J Behav Med. 2017; 40(1): 6–22.

Larsen KR, Michie S, Hekler EB, et al. Behavior change interventions: the potential of ontologies for advancing science and practice. J Behav Med. 2017; 40(1): 6–22.

Marques MM, Carey RN, Norris E, et al. Delivering Behaviour Change Interventions: Development of a Mode of Delivery Ontology [version 1; peer review: 1 approved, 1 approved with reservations]. Wellcome Open Res. 2020; Wellcome Open Research 2021, 6:77 Last updated: 21 NOV 2021

Zenodo: HumanBehaviourChangeProject/ontologies: HumanBehaviourChangeProject/ontologies: Upper-Level, Setting, Mode of Delivery & Source ontologies. https://zenodo.org/record/4476603#.

InterRater-Reliability: Release of HBCP inter-rater reliability code v1.0.0. (Version v1.0.0). Zenodo. 2020. http://www.doi.org/10.5281/zenodo.3838816

Reference Source

Acknowledgements

We are grateful to Ailbhe Finnerty, Candice Moore, Elizabeth Corker, Emily Hayes, Marta Marques and Silje Zink for annotating papers for inter-rater reliability testing.

Software availability

Source code used to calculate alpha for IRR available from: https://github.com/HumanBehaviourChangeProject/Automation-InterRater-Reliability.

Archived code at time of publication: https://doi.org/10.5281/zenodo.3833816 (Finnerty & Moore, 2020)

License: GNU General Public License v3.0 only
Michie S, Johnston M: Representation of behaviour change interventions and their evaluation: Development of the Upper Level of the Behaviour Change Intervention Ontology (version 2; peer review: 2 approved). Wellcome Open Res. 2021; 5: 122.

Michie S, West R, Fennerty AN, et al.: Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). Health Technol Assess. 2015; 19(99): 1–188.

Michie S, Thomas J, Aonghusa MP, et al.: The Human Behaviour-Change Project: An artificial intelligence system to answer questions about changing behaviour (version 1; peer review: not peer reviewed). Wellcome Open Res. 2020; 5: 126.

Michie S, West R, Fennerty AN, et al.: Optimising the value of the evidence generated in implementation science: the use of ontologies to address the challenges. Implement Sci. 2017; 12(1): 131.

Montgomery P, Grant S, Mayo-Wilson E, et al.: Reporting randomised trials of social and psychological interventions: the CONSORT SPI 2018 Extension. Trials. 2018; 19(1): 407.

Norris E, Fennerty AN, Hastings J, et al.: A scoping review of ontologies related to human behaviour change. Nat Hum Behav. 2019; 3(2): 164-172.

Norris E, Fennerty AN, Hastings J, et al.: The Human Behaviour-Change Project/ontologies: Upper-Level, Setting, Mode of Delivery & Source ontologies Submitted (Version v1.0). Zenodo. 2021.

Rauh SL, Turner DA, Jellison S, et al.: Completeness of Intervention Reporting of Clinical Trials Published in Highly Ranked Obesity Journals. Obesity (Silver Spring). 2021; 29(2): 285-293.

Rice VH, Heath L, Livingston-Banks J, et al.: Nursing interventions for smoking cessation. Cochrane Database Syst Rev. 2017; 12(12): CD001188.

Shindo H, Munesada Y, Matsumoto Y: PDFAnno: a web-based linguistic annotation tool for pdf documents. In: Proceedings of the Eleventh International Conference on Language Resources and Evaluation (LREC 2018). 2018.

Smith B, Ashburner M, Rosse C, et al.: The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration. Nat Biotechnol. 2007; 25(11): 1251-1255.

Smith B, Ceusters W, Klages B, et al.: Relations in biomedical ontologies. Genome Biol. 2005; 6(5): R66.
Open Peer Review

Current Peer Review Status: ? ✓ ✓

Version 1

Reviewer Report 27 August 2021

https://doi.org/10.21956/wellcomeopenres.18395.r45032

© 2021 Metrebian N. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Nicola Metrebian
Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, UK

This article reports on the development of an intervention source ontology for behaviour change interventions. The authors assert that identifying how behaviour change interventions are delivered, including by whom, is key to understanding their effectiveness. However, this information is reported inconsistently. The authors have set out to develop a methodology for consistently reporting who delivers behaviour change interventions (sources) as part of the Behaviour Change Intervention Ontology.

The authors are experts in their field and this is a well-designed and important study. Trials of behaviour change interventions need to be clearly reported to allow for interpretation of findings, replication and implementation of the intervention. This ontology will be hugely helpful. The authors use methods for ontology development and maintenance used in the Behaviour change Project. The methods have some limitations which the authors highlight in their discussion. These include, that the intervention reports used for the ontology development addressed only smoking cessation and physical activity behaviours and that there were few experts from less represented countries, thus potentially narrowing the ontology. The rationale, methods and results are set out clearly.

I have only a few minor comments.

Introduction

The authors state there are 3 components to delivering an intervention, mode of delivery, schedule and source. They mention that those delivering the intervention (source) may require certain levels of knowledge and skills, or to have undergone intervention specific training but don't elaborate. Training and on-going supervision are important for ensuring interventions are delivered effectively. The authors might consider adding a couple of sentences on the importance of training and supervision.

Results

The authors report on the numbers of stakeholders who responded to their request for
involvement (34) and responded from less represented countries (7/34). I understand 29 of the 34 completed the survey. Can they also include the numbers from less represented countries who completed the survey?

I was surprised to see psychologist parent class as social professional rather than health professional. I would have expected a clinical psychologist to have a parent class of health professional. Was this as a result of having all psychology disciplines in the same group? Might these have been better classified separately?

It's good to see supervision has been included in the ontology but it would be useful to have more detail around the definition ie. whether ongoing and frequency.

**Is the work clearly and accurately presented and does it cite the current literature?**
Yes

**Is the study design appropriate and is the work technically sound?**
Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**
Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**
Not applicable

**Are all the source data underlying the results available to ensure full reproducibility?**
Yes

**Are the conclusions drawn adequately supported by the results?**
Yes

**Competing Interests:** I have through my university (King’s College London) worked with the pharmaceutical industry on other areas of research but these are not relevant to this article.

**Reviewer Expertise:** Addiction, developing and evaluating behaviour change interventions, clinical trials of behaviour change interventions.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.
Thank you for the opportunity to review this manuscript which sought to develop an ontology for specifying who delivers interventions. This will be an important contribution for the implementation science field as it will support trialists in their reporting of interventions which is particularly important as the field is advancing in respect to adaptation and optimisation. The authors have presented a strong rationale for the need for the ontology, used and described robust methods for this study and presented the results clearly. I really enjoyed reviewing this paper and have minimal feedback for the authors, just a few questions that they may wish to consider. Congratulations.

When I read the title of paper I immediately thought of Justin Presseau et al work (i.e. AACTT) Framework which had built off TACT Framework. I wondered why this wasn't made mention of in your paper and how your ontology potentially links or extends this work?

In Step 2 the authors note that 100 published reports of behaviour change interventions were reviewed. It may not matter but I was wondering about the characteristics of these reports. It may be useful to just give a brief description of the characteristics of these studies.

The response rate in Step 4 was quite low. Do the authors think that this could have had any impact on the findings for the thematic analysis?

This may not be universal, but one issue that we often face in our work in community settings i.e. schools, childcare services is the employment status of the individuals (e.g. casual, temporary/permanent, part-time/fulltime) who are delivering the intervention. This has a big impact on implementation interventions that are impacted by staff turnover. I was left wondering if there was somewhere in the ontology where trialists could be encouraged to capture and report this.

Is the work clearly and accurately presented and does it cite the current literature? Yes

Is the study design appropriate and is the work technically sound? Yes

Are sufficient details of methods and analysis provided to allow replication by others? Yes

If applicable, is the statistical analysis and its interpretation appropriate? Yes

Are all the source data underlying the results available to ensure full reproducibility? Yes
Are the conclusions drawn adequately supported by the results?
Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Implementation Science

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 29 June 2021

https://doi.org/10.21956/wellcomeopenres.18395.r44393

© 2021 Lavoie K. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Kim Lavoie ID
1 Montreal Behavioral Medicine Centre, Centre intégré universitaire de santé et services sociaux du Nord de l’Île de Montréal (CIUSSS-NIM), Montreal, QC, Canada
2 University of Quebec at Montreal (UQAM), Montreal, QC, Canada

**Summary**
This paper reported on the methods for defining an Intervention Source Ontology, which is a subset of the Behaviour Change Ontology. Identifying how behaviour change interventions are delivered, including by whom, is critical for understanding how interventions work, as well as for replication. After conducting a stakeholder review with 34 behaviour and public health experts, his study identified 140 entities and includes occupational role of the source, relatedness between person source and the target population, sociodemographic characteristics and expertise. Inter-rater reliability of annotations was acceptable at about $\alpha=0.60$.

**Strengths**
This is a timely study on an important topic – defining an ontology that describes the ‘interventionist’ in the context of behavioural interventions. This is badly needed due to the high heterogeneity of existing terms used to describe interventionists in these studies, which limits replication and knowledge transfer. This work is judged to be high impact and will be of great interest to all researchers working in this field.

The authors clearly described the 7 steps they used to define the ontology, which were appropriate. Key strengths include engagement of relevant stakeholders across multiple phases of the work (behavioural and public health experts – with an effort to include experts from underrepresented countries), conducting inter-rater reliability testing of annotations, and providing a table with clear definitions and concrete examples that should guide future research.

**Weaknesses**
There were few weaknesses, but the paper and its contribution could be strengthened by addressing the following points:

1. Under step 4, it was reported that experts in behaviour and public health who were members of UCL's Center for Behaviour Change were engaged as stakeholders to conduct reviews. It would be helpful to clearly define what was considered an ‘expert’ in these areas – was this based on years of experience, relevant publications, etc? Or was any member of the CBH automatically eligible? If so, please clarify the criteria for membership.

2. Related to above, did you collect any demographic information on your experts – age, sex, years of experience, current position? You seem to have collected and reported information on their country of origin, but it would be helpful to know who the experts were to interpret their perspectives.

3. When considering expert feedback, did the research team establish a-priori any criteria for decision-making, for example, on whether to retain or move an entity, based on a certain proportion of experts making the suggestions? Or was this done at the discretion of the research team?

4. Table 2 was very clear and well-constructed. However, there are some entries that require further clarification. One regards the classification of psychologist. Based on the definition provided under ‘health professional’ – it would seem appropriate to include health psychologist here ("a professional that improves or develops concepts, theories and operational method, and applied scientific knowledge relating to medicine, nursing, dentistry, veterinary medicine, pharmacy, and promotion of health). With more than 20 years in the field, I personally don’t agree with health psychologists not being listed among the professionals in the example field.

5. Related to above, ‘psychologist’ appears as its own BCI source, but the decision to classify the very broad discipline of ‘psychologist’ as a ‘social professional’ rather than a ‘health professional’ (which may include mental health) is not clear. I am not convinced that psychologists can all be subsumed under the ‘social professional’ category - as most are actually clinicians who would be considered health professionals (mental health); and a subset of psychologists - health psychologists - either study the psychosocial and behavioural determinants of physical health and/or work as interventionists to influence physical health/disease outcomes/public health. The role of psychologist needs to be better nuanced here – perhaps the team could consider grouping those who work in areas where there are clear health or physical/mental outcomes (e.g., clinical psychologist, health psychologist, counselling, neuro, community health, sport/exercise) vs those who work in areas where there are more ‘social’ outcomes (e.g., educational, organizational, forensic, community). Psychologists may also be broadly categorized into those who are interventional (clinical, health, counselling, neuro) vs non-clinical interventional (educational, organizational) vs academic (developmental, social, etc.). Bottom line, I am not convinced the role of psychologist has been appropriately nuanced.

6. “Psychotherapist is a generic term for someone that conducts psychotherapy but is not a type of psychologist or a protected term, and a broad range of professionals may also be called psychotherapists including social workers, clergy etc. So I would remove, give it its own source definition, or add to other categories.
7. For “target behaviour of person source”, I am not sure I understand what this is – is it the extent to which the interventionist personally exhibits the target behaviour they are working on with participants? Please clarify. Idem for ‘psychological influence on intervention delivery of person source.

8. For ‘knowledge or skill’, please specify if pre-existing or acquired in preparation for the study.

9. For ‘acquired knowledge or skill’, please provide an example.

10. For ‘supervision of person source’, please provide an example of supervision (e.g., supervised through weekly meetings etc.).

11. For ‘payment of person source”, please provide an example.

12. For ‘source involved in co-production’, please clarify if co-production can only occur with patients/community members or can it also occur with HCP’s?

13. For ‘organization”, please provide examples. Idem for organization source role and organization source.

14. Minor comment: There is a typo on page 6 in the paragraph describing step 4 – should read “Australia”.

**Is the work clearly and accurately presented and does it cite the current literature?**
Yes

**Is the study design appropriate and is the work technically sound?**
Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**
Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**
Not applicable

**Are all the source data underlying the results available to ensure full reproducibility?**
Yes

**Are the conclusions drawn adequately supported by the results?**
Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Health psychology, behavioural medicine, behaviour change, behavioural intervention development methods, behavioural trial methods, chronic disease prevention
I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.