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RESEARCH ARTICLE

REVISED Behaviour change techniques taxonomy v1: Feedback to inform the development of an ontology [version 2; peer review: 2 approved]

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Abstract

Background: To build cumulative evidence about what works in behaviour change interventions, efforts have been made to develop classification systems for specifying the content of interventions. The Behaviour Change Techniques (BCT) Taxonomy v1 (BCTTv1) is one of the most widely used classifications of behaviour change techniques across a variety of behaviours. The BCTTv1 was intentionally named version 1 to allow for further revisions to the taxonomy. This study aimed to gather data to improve the BCTTv1 and provide recommendations for developing it into a more elaborated knowledge structure, an ontology.
Methods: Feedback from users of BCTTv1 about limitations and proposed improvements was collected through the BCT website, user survey, researchers and experts involved in the Human Behaviour-Change Project, and a consultation. In addition, relevant published research reports and other classification systems of BCTs were analysed. These data were synthesised to produce recommendations to inform the development of an ontology of BCTs.
Results: A total of 282 comments from six sources were reviewed and synthesised into four categories of suggestions: additional BCTs, amendments to labels and definitions of specific BCTs, amendments to the groupings, and general improvements. Feedback suggested some lack of clarity regarding understanding and identifying techniques from labels, definitions, and examples; distinctions and relations between BCTs; and knowing what they would look like in practice. Three recommendations to improve the BCTTv1 resulted

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Any reports and responses or comments on the article can be found at the end of the article.

from this analysis: to review the label and definition of each BCT, the 16 groupings of BCTs, and the examples illustrating BCTs.
Conclusions *:* This review of feedback about BCTTv1 identified the need to improve the precision and knowledge structure of the current taxonomy. A BCT ontology would enable the specification of relationships between BCTs, more precise definitions, and allow better interoperability with other ontologies. This ontology will be developed as part of the Human Behaviour-Change Project.

Keywords
behaviour change techniques, taxonomy, ontology, user feedback, intervention reporting

This article is included in the Human Behaviour-Change Project collection.

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REVISED **Amendments from Version 1**

This version of the manuscript includes changes made in response to the comments and suggestions from the two reviewers. Specifically, we provide more detail on the methods used to collect and analyse the feedback, as well as a clarification of the aims of the manuscript. We also replaced Table 3 and Table 4 with a flowchart displaying the number of comments from each feedback source, the number of comments removed from the analysis and the reasons for that exclusion.

Any further responses from the reviewers can be found at the end of the article

Introduction

To build cumulative evidence about 'what works' for behaviour change interventions aiming to influence human behaviours, efforts have been made to develop classification systems for specifying the content of interventions. Examples include behaviour change techniques (BCTs), defined as planned processes that are the smallest parts of the content of a behaviour change intervention that are observable, replicable and on their own have the potential to bring about behaviour change (Michie *et al.,* 2021). These classifications provide a standardized way and common language to describe BCTs, contributing to the improvement of intervention reports and evidence syntheses, and as a result, to the implementation of effective behaviour change interventions in research and practical settings.

The Behaviour Change Techniques Taxonomy v1 (BCTT v1) (Michie *et al.,* 2013) is the most widely used classification of BCTs. The BCTTv1 provides a list of 93 clearly labelled and defined BCTs, organised in 16 higher-order groupings representing the function of the BCTs in each group, e.g. group 1 refers to goals and planning BCTs. The BCTTv1 was developed over an iterative programme of research studies (Michie *et al.*, 2015). This involved identifying commonly used techniques in interventions across various health behaviours, labelling and description of distinct and non-overlapping techniques, consultation with experts for feedback on the BCTs, development of a hierarchical structure, and validation of the BCTTv1 through coding intervention reports (Michie *et al.,* 2013; Michie *et al.,* 2015). Four hundred experts from around the world contributed to the development and validation of BCTTv1. Resources were developed to support the use of BCTTv1, including an app (www.ucl.ac.uk/health-psychology/bcttaxonomy/BCT_app1), a database of studies of interventions coded using BCTTv1 (www.bct-taxonomy.com/interventions), and online training to guide the identification of BCTs in published papers (www.bct-taxonomy.com/).

The BCTTv1 has been widely adopted, tested, and applied internationally (e.g., >1400 people from 33 countries/13 low- and middle-income countries (LMIC)s have participated in the BCTTv1 training; 4,830 citations of the main BCTTv1 papers (Michie *et al.,* 2013; Michie *et al.,* 2015)). The BCTTv1 has been mainly used to identify, through systematic reviews and meta-analysis, the presence of individual BCTs and groups of BCTs that are more frequently used and/or more effective across a wide range of behaviour change interventions in diverse populations (West *et al.,* 2020a). It has also been used to inform intervention design and evaluation, frequently through its integration in the Behaviour Change Wheel Framework (Michie *et al.,* 2011). The Behavior Change Wheel is an integrative framework that derived from a synthesis of 19 frameworks to aid the systematic development and evaluation of behavior change interventions and has been used across a wide range of behaviours and to inform policy (West *et al.,* 2020b). The framework provides a systematic way of identifying i. a problem in behavioural terms, ii. what needs to change for the target behaviour to change in terms of capabilities, opportunities, and motivation (COM-B model), iii. the relevant intervention functions and techniques to change the target behaviour, and iv. the relevant policy categories (societal or organizational strategies) for implementing sustained behavioural changes.

The BCTTv1 was named 'version 1' to signal that further revisions would be expected based on; 1) emerging evidence, 2) feedback from users for updating, advancing, and increasing the scientific and practical value of BCTTv1 (e.g., additional BCTs, structural changes), and 3) new knowledge on alternative improved classification methods.

Ontologies offer a more comprehensive and expressive way of representing information than taxonomies (Hastings, 2017). 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.,* 2021). The BCIO consists of an upper level with 42 entities, specifying features of behaviour change interventions, such as mode of delivery (Marques *et al.,* 2021), source of the intervention (Norris *et al.,* 2021), and the setting where the intervention takes place (Norris *et al.,* 2020). One of the entities in the BCIO is BCT, specified as part of the content in a given behaviour change intervention scenario (Michie *et al.,* 2021).

Ontologies are inter-operable, which means that an ontology of BCTs can be linked to the other entities specified in the BCIO as well as to other relevant social, behavioural, and interventions ontologies, allowing integration of evidence across disciplinary and topic domains. This enables the answering of questions about the effectiveness of behaviour change interventions and how effects are modified according to different behaviours and characteristics of the population and setting, and about the way components of intervention work together to achieve behaviour change. As well as advancing understanding about variation in effects across interventions, an ontology of behaviour change interventions can advance understanding of processes of change, i.e., their mechanisms of action. As ontologies are computer-readable, they can be used to synthesise large amounts of data using artificial-intelligence based methods (e.g. natural language processing, machine learning) to provide evidence-based knowledge on the components of behaviour change interventions that are more effective and how they relate with each other.

The primary aim of this study was to gather data with which to update the BCTTv1. This paper reports an analysis of feedback

about BCTTv1 from experts and intervention developers from a variety of fields. Feedback was sought on the limitations and associated improvements that could be made to BCTTv1. The latter included adding BCTs, improving BCT labels and definitions, and changing groupings and structure. Recommendations for developing the BCTTv1 into a BCT Ontology are made based on the feedback.

Methods

Ethical statement

Ethical approval was granted by University College London's ethics committee (CEHP/2016/555). Informed consent was obtained from participants prior to participation in the surveys that were conducted as part of this study, by indicating in the surveys if their answers could be published

Design

This study consisted of three stages: 1) seeking feedback from users of the BCTTv1, 2) synthesising feedback, and 3) producing recommendations relating to improvements to classification of BCTs. Participant consent was gained for each source of feedback.

Stage one: Gathering feedback about the BCTTv1

Feedback about the limitations and proposed improvements to the BCTTv1 was sought from several sources: 1) researchers from the Human Behaviour-Change Project who coded 512 papers using the BCTTv1; 2) data from the Theory and Techniques Project expert consensus exercise (Connell *et al.,* 2019); 3) two online surveys designed to gather feedback regarding BCTs; 4). a consultation exercise with users of BCTs, including researchers and implementers; 5) relevant published research reports proposing new BCTs and/or changes to BCTTv1 or other classification systems of BCTs. The online surveys were conducted using Qualtrics. Definitions for additional BCTs found within other classification systems were added to the dataset verbatim from the relevant publication. The first survey was open to any user of the BCTTv1 wishing to provide feedback about BCTs that were not included in the BCTTv1, amendments to BCTs, BCTs that were difficult to use, adaptations and translations of the BCTTv1, data on reliability, and general suggestions for improvements. The survey contained closed and open-ended questions. Recruitment was conducted through advertising the link to the survey in social media, and Centre for Behaviour Change Newsletters. The second survey inquired about the use of the BCTTv1 (reason for using, research questions addressed when using the BCTTv1) and general improvements to be made to the BCTTv1. Recruitment was conducted via email, contacting BCTTv1 users who had previously signed up to a list of stakeholders for the Human Behaviour-Change Project. Details for each source of feedback are summarised in Table 1 and details for each paper reviewed are summarised in Table 2.

Stage two: Synthesising feedback

Data from each source of feedback relating to the BCTTv1 were reviewed by two authors (EC and MM). A content analysis was performed on the data collected from the BCTTv1 user survey (EC).Four broad categories of feedback were formed based on the main issues raised: additional BCTs, amendments to labels or definitions of BCTs, amendments to the BCT groupings, and general improvements. Two authors (EC and MM) used these categories to code the remaining sources of feedback jointly (via online meetings). As this process was undertaken jointly, no interrater reliability data was produced. Data were synthesised into a single document, enabling examination across each data source (see underlying data - full extraction data) (West *et al.,* 2020a). Authors then discuss each recommendation and how they could be addressed. Suggestions to change any aspects of the BCTTv1 were then discussed with the core research team. The outputs from the initial review were then discussed and revised by two authors (EC and MJ).

Stage three: Producing recommendations on developing BCTTv1 into a BCT ontology

Five behavioural science experts (EC, MM, MJ, SM, and RW) and one ontology expert (JH) reviewed each comment in the output from Stage 2 and drafted and then refined recommended actions relating to each piece of feedback. In addition to the synthesised feedback, each BCT label and definition was reviewed to ensure that they were consistent with good ontological practice (Michie *et al.,* 2019) and that each label is aligned with its definition (Michie *et al.,* 2021), that is, each BCT should be: 1) a planned process, 2) the smallest part of an intervention that on its own can bring about change in behaviour 3) observable, 4) replicable, and 5) have the potential to bring about behaviour change. A list of recommendations relating to the labels and definitions of BCTs, along with the structure, hierarchy and relationships was produced.

Results

Stage one: Feedback about BCTTv1

Feedback was gathered from several sources: 1) researchers from the Human Behaviour-Change Project (n=4 researchers; 512 papers coded for BCTs); 2) data from the Theory and Techniques Project expert consensus exercise (n=105); 3) two online surveys designed to gather feedback regarding BCTs (BCTTv1 online portal n=27 and BCTTv1 user survey n=68); 4) a consultation exercise with users of BCTs, including researchers and implementers (n=22); 5) relevant published research reports proposing new BCTs and/or changes to BCTTv1 or other classification systems of BCTs (n=11). The number of users that contributed to each feedback source ranged from 22 to 105.

The forward citation search identified 2,562 research reports. In eight of these reports, a behaviour classification system, recommendations for revisions to specific BCTs, or recommendations for revisions to the BCTTv1 were identified (Table 2). Seven of these were also identified by either a participant in the user feedback exercises or the research team. A further three research reports were suggested by the research team and two more were suggested by a participant in the user feedback exercises, giving a total of 13 reports. Two were not taken forward to the data analysis process because they described general ways of thinking about behaviour rather than BCTs.

Stage two: Synthesis of feedback

A total of 438 comments from the feedback exercises and published reports were reviewed. Figure 1 reports the number of comments reviewed from each feedback source the numbers

Table 1. Sources of Behaviour Change Techniques Taxonomy v1 (BCTTv1) feedback.

Feedback source	Type and treatment of data	Year data collected and reference/ website
1. Human Behaviour-Change Project	Qualitative analysis of documents related to the annotations of BCTs in intervention reports using the BCTTv1. Research activities within the Human Behaviour Change Project relating to the development of the Behaviour Change Intervention Ontology have included keeping notes relating to the use of BCTs and the BCTTv1.	2017–2018 https://www.humanbehaviourchange.org/
2. Theory and Techniques Project (Connell *et al.*, 2019)	Secondary analysis of qualitative data relating to the Theory and Techniques project. As part of the Theories and Techniques project 105 behaviour science experts provided comments regarding BCTs.	2015
3. BCTTv1 online feedback portal (West *et al.*, 2020a)	Qualitative analysis of data collected from BCTTv1 users through an open online portal. A portal on the BCTs Taxonomy v1 website allowed users to submit comments on the BCTs and the BCTTv1.	2015–2020
4. Consultation report (West *et al.*, 2020a)	Secondary analysis of qualitative data relating to use of the BCTs Taxonomy v1. A consultation exercise was completed, during which participants provided comments relating to their use of BCTs or the BCTTv1.	2019
5. BCTTv1 user survey (West *et al.*, 2020a)	Qualitative analysis of data collected from BCTTv1 users. Researchers and behaviour scientists completed a survey designed to provide feedback regarding their use of BCTs or the BCTTv1. This survey was conducted to gather additional feedback to what was collected through the online feedback portal.	2021
6. Reports of behaviour classification systems or BCTs	Secondary analysis of qualitative data related to BCTs or the BCTTv1. Several research reports have been published that outline behaviour classification systems or give direct recommendations for revisions to specific BCTs. Relevant research reports were identified by: • participants in the feedback exercises • correspondence sent to the research team • a forward citation search, conducted in 2021, from the BCTTv1 development, published in 2013.	2022

of comments removed from the analysis and the reasons for removal. During an initial screening process, 156 comments were removed from the analysis. Reasons for removing comments were:

- the comment contained a suggestion that was deemed to be beyond the scope of the development of BCTs
- the suggestion made had already been incorporated into other Behaviour Change Intervention Ontology work
- a specific suggestion was not made
- the suggestion did not fit with the study definition of behaviour or of behaviour change technique.

The remaining 282 comments were reviewed and sorted into four categories of suggestion: additional BCTs (n=32), amendments to the labels or definitions of BCTs (n=92), amendments to BCT groupings (n=9), and general improvements (n=17). These numbers do not equal the total number of comments as

Table 2. Papers initially reviewed.

Behaviour classification system related paper	Source of identification	Inclusion in analysis
Towards a taxonomy of behaviour change techniques for promoting shared decision making (Agbadjé *et al.*, 2020)	Forward citation search	Yes
MINDSPACE (Dolan *et al.*, 2010)	Suggested by research team and identified by survey participant, consultation	Yes
A systematic review of recruitment strategies and BCTs in group-based diabetes prevention programmes focusing on uptake and retention (Begum *et al.*, 2020)	Sent to research team and forward citation search	Yes
BCTs associated with smoking cessation in intervention and comparator groups of randomized controlled trials: a systematic review and meta-regression (Black *et al.*, 2020)	Identified by HBCP team and forward citation search	Yes
Social norms interventions to change clinical behaviour in health workers: a systematic review and meta-analysis (Cotterill *et al.*, 2020)	Identified by survey participant, and forward citation search	Yes
Assessing and promoting the use of implementation intentions in clinical practice (Duhne *et al.*, 2020)	Identified by survey participant, and forward citation search	Yes
Identifying content-based and relational techniques to change behaviour in motivational interviewing (Hardcastle *et al.*, 2017)	Identified by survey participant, and portal and forward citation search	Yes
The TIPPME intervention typology for changing environments to change behaviour (Hollands *et al.*, 2017)	Identified by survey participant, in TaT project and forward citation search	Yes
The compendium of self-enactable techniques to change and self-manage motivation and behaviour v.1.0 (Knittle *et al.*, 2020)	Identified by survey participant portal	Yes
A taxonomy of behaviour change methods: an Intervention Mapping approach (Kok *et al.*, 2016)	Suggested by research team	Yes
Social prescribing and behaviour change: proposal of a new behaviour change technique concerning the 'connection' step (Cunningham *et al.*, 2022)	Sent to research team and forward citation search	Yes
EAST Four simple ways to apply behavioural insights (The Behavioural Insights Team, 2014)	Suggested by research team and identified by survey participant, consultation	No
Everything should be as simple as possible, but no simpler: towards a protocol for accumulating evidence regarding the active content of health behaviour change interventions (Peters *et al.*, 2015)	Identified by survey participant user survey	No

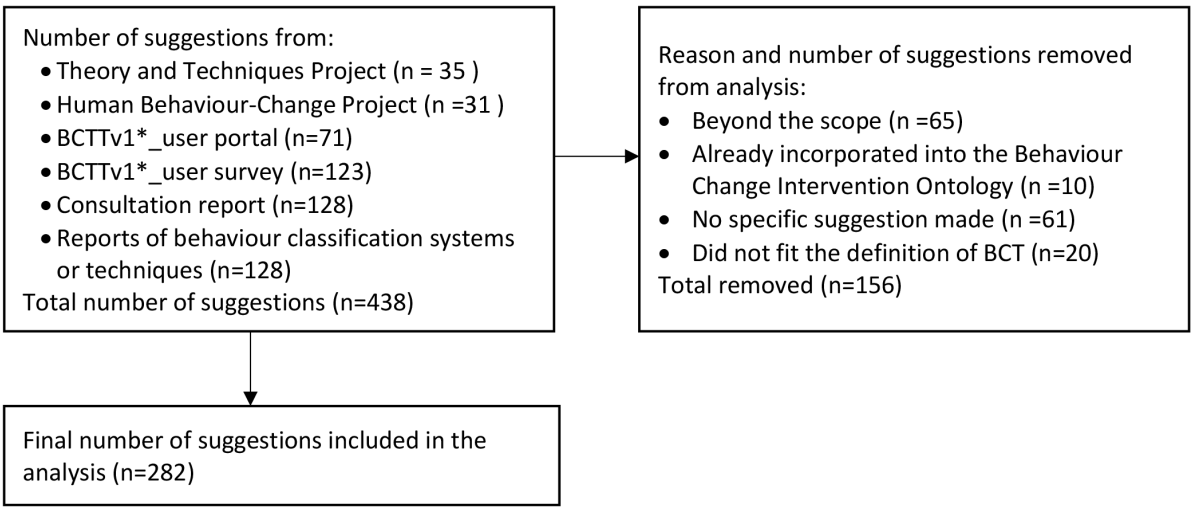
some comments were sorted into more than one category, and several comments contained the same suggestion. (West *et al.*, 2020)

Additional BCTs

32 comments were made, containing 47 suggestions for new BCTs. A further 22 BCTs were considered by participants to be more than one technique. Review by the research team resulted in 22 suggestions for new BCTs, to be further developed in an ontology of BCTs.

Labels or definitions of BCTs

92 comments contained suggestions relating to amending a BCT label or definition. The number of suggestions made per BCT ranged from 0–11 (Table 3). Based on these comments, the research team developed recommendations for revision of labels and definitions for each BCT, taking into consideration ontological best practice (Michie *et al.*, 2019; Michie *et al.*, 2021). Amendments should be made to all BCT labels to ensure that each label is clearly aligned to a specific BCT definition. Additionally, in accordance with ontological best practice, existing BCTs in the BCTTv1 that refer to more than one technique in their definition should be separated into more than one distinct BCT. For example, the BCT in the BCTTv1 'problem solving' should be separated into 'problem solving BCT' (referring to person analysing factors influencing the behaviour and generating and selecting strategies to overcome barriers) and 'prompt problem solving BCT' (referring to the source prompting the person to analyse factors influencing the behaviour and generating and selecting strategies to overcome barriers. Brackets should also be removed from BCT labels, for example, the label 'goal setting (behaviour)' should be 'set behavioural goal BCT' . In addition, the beginning of each BCT definition should be amended to ensure that the



* Behaviour Change Techniques Taxonomy v1

Figure 1. Number of comments from each feedback source and number of comments removed from the analysis and the reason.

Table 3. Number of suggestions made related to the label, definition or example of specific behaviour change techniques (BCTs).

BCTTv1* no.	BCTTv1 label	N of comments
1.1	Goal setting (behaviour)	6
1.2	Problem Solving	4
1.3	Goal setting (outcome)	2
1.4	Action planning	6
1.5	Review behaviour goal(s)	0
1.6	Discrepancy between current behaviour and goal	2
1.7	Review outcome goal(s)	0
1.8	Behavioural contract	1
1.9	Commitment	2
2.1	Monitoring of behaviour by others without feedback	1
2.2	Feedback on behaviour	1
2.3	Self-monitoring of behaviour	2
2.4	Self-monitoring of outcome(s) of behaviour	1
2.5	Monitoring outcome(s) of behaviour by others without feedback	0
2.6	Biofeedback	0
2.7	Feedback on outcome(s) of behaviour	1
3.1	Social support (unspecified)	11
3.2	Social support (practical)	1
3.3	Social support (emotional)	2
4.1	Instruction on how to perform a behaviour	3
4.2	Information about antecedents	2
4.3	Re-attribution	1
4.4	Behavioural experiments	0
5.1	Information about health consequences	1
5.2	Salience of consequences	3
5.3	Information about social and environmental consequences	0
5.4	Monitoring of emotional consequences	1
5.5	Anticipated regret	2
5.6	Information about emotional consequences	2
6.1	Demonstration of the behaviour	2
6.2	Social comparison	2
6.3	Information about others' approval	3
7.1	Prompts/cues	1
7.2	Cue signalling reward	1
7.3	Reduce prompts/cues	0

BCTTv1* no.	BCTTv1 label	N of comments
7.4	Remove access to the reward	0
7.5	Remove aversive stimulus	0
7.6	Satiation	0
7.7	Exposure	1
7.8	Associative learning	1
8.1	Behavioural practice/ rehearsal	4
8.2	Behaviour substitution	0
8.3	Habit formation	0
8.4	Habit reversal	1
8.5	Overcorrection	0
8.6	Generalisation of a target behaviour	0
8.7	Graded tasks	5
9.1	Credible source	6
9.2	Pros and cons	2
9.3	Comparative imagining of future outcomes	1
10.1	Material incentive (behaviour)	1
10.2	Material reward (behaviour)	5
10.3	Non-specific reward	2
10.4	Social reward	1
10.5	Social incentive	1
10.6	Non-specific incentive	2
10.7	Self-incentive	3
10.8	Incentive (outcome)	1
10.9	Self-reward	5
10.10	Reward (outcome)	0
10.11	Future punishment	4
11.1	Pharmacological support	4
11.2	Reduce negative emotions	4
11.3	Conserving mental resources	0
11.4	Paradoxical instructions	0
12.1	Restructuring the physical environment	7
12.2	Restructuring the social environment	4
12.3	Avoidance/reducing exposure to cues for the behaviour	2
12.4	Distraction	1
12.5	Adding objects to the environment	4
12.6	Body changes	3
13.1	Identification of self as role model	0
13.2	Framing/reframing	1
13.3	Incompatible beliefs	0
13.4	Valued self-identity	5
13.5	Identity associated with changed behaviour	2
14.1	Behaviour cost	1
14.2	Punishment	2
14.3	Remove reward	1
14.4	Reward approximation	0
14.5	Rewarding completion	0
14.6	Situation-specific reward	0
14.7	Reward incompatible behaviour	1
14.8	Reward alternative behaviour	1
14.9	Reduce reward frequency	1
14.10	Remove punishment	0
15.1	Verbal persuasion about capability	3
15.2	Mental rehearsal of successful performance	0
15.3	Focus on past success	1
16.1	Imaginary punishment	1
16.2	Imaginary reward	0
16.3	Vicarious consequences	2

*Behaviour Change Techniques Taxonomy v1

definition is clearly aligned to a specific grouping, for example, the research team proposes that the start of the definition for 'set behavioural goal BCT' is 'A goal setting BCT that sets a goal for behaviour to be achieved', where 'goal directed BCT' is the label for the specific group in which 'set behavioural goal BCT' is placed.

Frequently reported issues

The issue reported most frequently was a lack of clarity of BCT labels and definitions (121 comments). Examples are (for full details, please see West *et al.,* 2020b).

"Clarify that this is more specific than the everyday use of the term by enhancing the 'what it is not" (1.4 Action planning)

"Clarify definition to include rewards from participants 'naturally' or integrated in interventions by design" (10.2 Material reward (behaviour))

"Needs more specificity to avoid being a 'catch-all'" (3.1 Social support (unspecified)).

Fourteen comments referred to difficulties in distinguishing between BCTs, for example

"Better differentiation needed between 10.7 self-incentive and 10.9 self-reward labels" (10.7 Self incentive).

Amendments to BCTTv1 groupings

Nine comments were made in relation to the 16 BCTTv1 groupings, with each grouping attracting up to four comments (Table 4). Content of the feedback consisted of requests for

Table 4. Number of suggestions made relating to each grouping of behaviour change techniques (BCTs).

BCTTv1* grouping no.	BCTTv1 grouping label	N of comments
1.	Goals and planning	1
2.	Feedback and monitoring	1
3.	Social support	0
4.	Shaping knowledge	0
5.	Natural consequences	2
6.	Comparison of behaviour	1
7.	Associations	0
8.	Repetition and substitution	0
9.	Comparison of outcomes	0
10.	Reward and threat	4
11.	Regulation	0
12.	Antecedents	0
13.	Identity	0
14.	Scheduled consequences	0
15.	Self-belief	0
16.	Covert learning	0

*Behaviour Change Techniques Taxonomy v1

clarification of group definitions and creations of new groups. This feedback reinforced the need to review the original BCT groupings, taking into consideration ontological principals.

Stage three: Recommendations for ontology development

Based on Stage two, three recommendations were made for the next stage of developing the BCT ontology.

1. Review the label and definition of each BCT to ensure that they are consistent with good ontological practice and that each label is aligned with its definition (Michie *et al.,* 2019; Michie *et al.,* 2021),

2. Review each of the 16 groupings that contain BCTs. Each grouping should be inclusive, that is, the grouping should capture each relevant BCT, as well as exclusive, that is, the grouping should not describe aspects of BCTs that appear in other groupings.

3. Review the examples that are given to illustrate BCTs. Examples of BCTs should span behavioural domains and illustrate only the BCT it is an example of.

Discussion

The widespread international use of BCTs through systematic reviews and meta-analysis, along with intervention design, implementation and evaluation (Armitage *et al.,* 2021) demonstrates the utility and need for a BCT classification system. The feedback synthesis and review benefited from the use of six sources of feedback generating almost 300 comments but was inevitably constrained in scope by study resources. The study of expert user views found that the BCTTv1 classification system could be improved. A total of 282 comments were reviewed and synthesised into four categories of feedback producing three recommendations for future development. These were to review the label and definition of each BCT, the BCT groupings, and the examples to illustrate BCTs.

This review of feedback about BCTTv1 identified the need to improve the precision and knowledge structure of the current taxonomy. The recommendations from this review and synthesis of extensive feedback relating to BCTs will enable a shared understanding of how best to conceptualise and organise BCTs in relation to each other.

From the revision of the BCTTv1 it became clear that this classification would benefit from an ontological structure, enabling clearer internal relationships between different BCTs, as well as relationships between BCTs and other aspects of behaviour change interventions such as mechanisms of action.

These findings will serve as the basis of developing BCTTv1 into a BCT Ontology. In addition to allowing specification of relationships within the ontology and interoperability with other ontologies, this transformation will also support the future sustainability of the classification: as ontology groupings are based on logical relationships between entities, development of a BCT Ontology will allow for subsequently identified entities to be added where they fit logically, without disrupting previously specified relationships. It will also allow for integration of BCTs within the broader Behaviour Change Intervention Ontology being developed by the Human Behaviour-Change Project (Michie *et al.,* 2017; Michie *et al.,* 2021), such as source (Norris *et al.,* 2021), mode of delivery (Marques *et al.,* 2021), setting (Norris *et al.,* 2020), and mechanisms of action (West *et al.*, 2020a) which in turn will allow annotations and users to access content via a single technical framework and a common set of tools.

By linking with the BCIO, the BCT ontology will be a valuable method for investigating the effectiveness of BCTs across contexts, such as populations and settings, and across types of behaviour. It also facilitates the investigation of processes of change, by linking BCTs with their potential mechanisms of action, building on the Theory and Techniques tool (https://theoryandtechniquetool.humanbehaviourchange.org/). Since ontologies are not static but can be developed to reflect scientific advance, more granular representation or further improvements. Further, a BCT ontology will also allow

for continuing development regarding definitions, labels and additional BCTs.

Limitations

Several limitations should be noted in this research. First, the sample sizes from the survey and open online portal were small, although efforts were made in disseminating these tools within the scientific community. Secondly, the papers proposing changes to BCTs were those the wider research team were familiar with rather than reflecting a systematic literature search. However, we considered this not to be a significant problem given that we drew on a number of diverse sources of feedback. Thirdly, the changes to the BCTs and groupings that were conducted in this study were only reviewed and discuss by the research team, they were not reviewed or tested by BCTTv1 users. An expert consultation activity will be conducted as part of the BCIO development.

Conclusion

Feedback from users and experts identified a number of ways in which BCTTv1 could be improved including improved labels, definitions and groupings. The analysis of the feedback to the BCTTv1 provides a solid basis for further research development work to create a BCT Ontology that can link up with other ontologies related to behaviour change. This work as a clear practical implication as it identifies the main issues experienced by interventionists using the BCTTv1 and provides clear recommendations for developing a better classification system of BCTs crucial to improve the quality of intervention reporting and evidence synthesis.

Data availability

Underlying data

Open Science Framework: Human Behaviour-Change Project > Behavioural Science > Exposure > Intervention > Content > BCTTv1 Feedback paper. https://doi.org/10.17605/OSF.IO/EFP4X (West *et al.*, 2020)

This project contains the following underlying data:

- Full Extraction data. (file containing the data extracted and analysed from all sources consulted in the study)

Extended data

Open Science Framework: Human Behaviour-Change Project > Behavioural Science > Exposure > Intervention > Content > BCTTv1 Feedback paper. https://doi.org/10.17605/OSF.IO/EFP4X (West *et al.*, 2020)

This project contains the following extended data:

- BCTTv1 Online Form. (Questions asked in the Online form made available to anyone wishing to contribute)
- BCTTv1 User Survey (Questions asked in the BCTTv1 User survey)
- UCL BCT Social Enterprise Business Case Report (Report of of informal qualitative research undertaken with users of the BCTTv1)

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

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Open Peer Review

Current Peer Review Status: ✔ ✔

Version 2

Reviewer Report 06 February 2023

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✔ **Stephan Dombrowski**
Faculty of Kinesiology, University of New Brunswick, Fredericton, NB, Canada

I approve of this updated version.

Competing Interests: No competing interests were disclosed.

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 25 January 2023

https://doi.org/10.21956/wellcomeopenres.20917.r54428

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✔ **Chris Keyworth**
Manchester Centre for Health Psychology, Division of Psychology and Mental Health, University of Manchester, Manchester, UK

I wish to thank the authors for the thoughtful and detailed response to the previous comments. These have all been addressed and I am happy to recommend publication.

Competing Interests: No competing interests were disclosed.

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.

Version 1

Reviewer Report 22 December 2022

https://doi.org/10.21956/wellcomeopenres.19961.r53017

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Stephan Dombrowski
Faculty of Kinesiology, University of New Brunswick, Fredericton, NB, Canada

Thanks for the opportunity to review this manuscript. I include some minor comments below for the authors to consider.

Minor point: “Aberdeen Health Psychology Group, University of Aberdeen, Aberdeen, USA”, p.1 - The Aberdeen referred to here is in Scotland, UK.

Minor point: “A comprehensive Behaviour Change Intervention Ontology (BCIO) is being developed as part of the Human Behaviour-Change (Michie *et al.*, 2017; Michie *et al.,* 2021).” – p. 3 should read Human Behaviour Change Project.

“This enables the answering of questions about the effectiveness of behaviour change interventions and how effects are modified according to different behaviours and contexts (populations and settings), and about the way components of intervention work together to achieve behaviour change.”, p.3 – Why does this sentence include populations and settings in brackets? Are these examples of context components, or related to them in some way? It would be useful to integrate these fully into the sentence.

The paper states that the aim is “to gather data with which to update the BCTTv1 and convert it into a BCT ontology.” (p.3). The first aim I can see being met, but there is no conversion into a BCT ontology, which is beyond the scope of the paper. Perhaps rephrase as gathering information which would inform the conversion, or something along those lines?

The level headings in the methods section are a little confusing to me. Are ‘Design and sample’ a level 2 heading, with ‘Stage one…’, ‘Stage two…’, etc. as level 3 headings underneath it? In general, the information presented in the methods section is more about the information sources than samples. Perhaps the level of the headers can be reviewed and the term ‘sample’ can be reviewed to ensure it is in line with the presented information.

Under the heading “Stage one: Gathering feedback about the BCTTv1” the authors outline 5 sources of information, but Table 1 lists 6 sources.

A bit more details as to how relevant papers for new BCTs were identified would add value. For example, did the authors examine all systematic reviews which used BCT v1 to code intervention content for potential proposals of new BCTs and/or amendments to labels and definitions? This

could have been a substantial study in itself.

How were behaviour classification systems included in the dataset? These provide alternative (albeit often overlapping) techniques and definitions, but are not comments in themselves. Were different techniques which were included in another classification system conceptualised as a comment in the analysis?

For ease of reading, Table 3 and 4 could be combined in a flowchart, rather than two separate tables. The flowchart could also include the final number of interest (282 comments), which currently only appears in the text.

Were there no comments at all made to the examples provided alongside the BCT definitions and labels? Having read on, it seems that examples were included as part of this category, as suggested by the sentence "92 comments contained suggestions relating to amending a BCT label, definition or example" (p.7). I would suggest to include examples as part of the category label, as these are important.

Can the sentences "Additionally, in accordance with ontological best practice, BCTs that refer to two separate techniques within the same definition should be separated out, for example, 'problem solving' should be 'problem solving BCT' and 'prompt problem solving BCT'."(p.7) be clarified? Does this suggest that using problem solving as a BCT is a separate technique from prompting the use of problem solving?

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?
Partly

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: behaviour change

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.

Author Response 10 Jan 2023

Marta Marques, NOVA Medical School|Faculdade de Ciências Médicas (NMS|FCM,) Universidade Nova de Lisboa, Lisboa, Portugal., Portugal

Thanks for the opportunity to review this manuscript. I include some minor comments below for the authors to consider.

- *We would like to thank the reviewer for the positive feedback on our manuscript. We have addressed all comments raised.*

Minor point: “Aberdeen Health Psychology Group, University of Aberdeen, Aberdeen, USA”, p.1 - The Aberdeen referred to here is in Scotland, UK.

- *We thank the reviewer for noticing this typo, we have no updated the affiliation to "Scotland, United Kingdom".*

Minor point: “A comprehensive Behaviour Change Intervention Ontology (BCIO) is being developed as part of the Human Behaviour-Change (Michie *et al.*, 2017; Michie *et al.,* 2021).” – p. 3 should read Human Behaviour Change Project.

- *We have corrected the sentence to include the word project.*

“This enables the answering of questions about the effectiveness of behaviour change interventions and how effects are modified according to different behaviours and contexts (populations and settings), and about the way components of intervention work together to achieve behaviour change.”, p.3 – Why does this sentence include populations and settings in brackets? Are these examples of context components, or related to them in some way? It would be useful to integrate these fully into the sentence.

- *Thank you for the suggestion. We changed the sentence to: "*This enables the answering of questions about the effectiveness of behaviour change interventions and how effects are modified according to different behaviours and characteristics of the population and setting, and about the way components of intervention work together to achieve behaviour change".

The paper states that the aim is “to gather data with which to update the BCTTv1 and convert it into a BCT ontology.” (p.3). The first aim I can see being met, but there is no conversion into a BCT ontology, which is beyond the scope of the paper. Perhaps rephrase as gathering information which would inform the conversion, or something along those lines?

- *We thank the reviewer for the suggestion and understand the aim could be misleading for the reader as it was stated. We have changed the paragraph as follows: "The primary aim of this study was to gather data with which to update the BCTTv1. This paper reports an analysis of feedback about BCTTv1 from experts and intervention developers from a variety of fields. Feedback was sought on the limitations and associated improvements that could be made to BCTTv1. The later including adding BCTs, improving BCT labels and definitions, and changing groupings and structure. Recommendations for developing the BCTTv1 into a BCT Ontology are made based on the feedback."*

The level headings in the methods section are a little confusing to me. Are 'Design and sample' a level 2 heading, with 'Stage one…', 'Stage two…', etc. as level 3 headings underneath it? In general, the information presented in the methods section is more about the information sources than samples. Perhaps the level of the headers can be reviewed and the term 'sample' can be reviewed to ensure it is in line with the presented information.

- *We have changed as suggested by the reviewer.*

Under the heading "Stage one: Gathering feedback about the BCTTv1" the authors outline 5 sources of information, but Table 1 lists 6 sources.

- *In the text we refer to the two surveys only once that is why the numbers do not correspond to the six sources in the table.*

A bit more details as to how relevant papers for new BCTs were identified would add value. For example, did the authors examine all systematic reviews which used BCT v1 to code intervention content for potential proposals of new BCTs and/or amendments to labels and definitions? This could have been a substantial study in itself.

- *We appreciate the reviewer comment. Research reports were only identified if they explicitly suggested a new BCT/recommendation for revision/new classification system. We did not have the resources to code systematic reviews or interventions.*

How were behaviour classification systems included in the dataset? These provide alternative (albeit often overlapping) techniques and definitions, but are not comments in themselves. Were different techniques which were included in another classification system conceptualised as a comment in the analysis?

- *To clarify this point, we have added the following information: "5) relevant published research reports proposing new BCTs and/or changes to BCTTv1 or other classification systems of BCTs. Definitions for additional BCTs found within other classification systems were added to the dataset verbatim from the relevant publication."*

For ease of reading, Table 3 and 4 could be combined in a flowchart, rather than two separate tables. The flowchart could also include the final number of interest (282 comments), which currently only appears in the text.

- *As suggested, we have now produced a flowchart instead of tables 3 and 4. We agree it is much better for the reader to have this information in a flowchart. Thank you.*

Were there no comments at all made to the examples provided alongside the BCT definitions and labels? Having read on, it seems that examples were included as part of this category, as suggested by the sentence "92 comments contained suggestions relating to amending a BCT label, definition or example" (p.7). I would suggest to include examples as part of the category label, as these are important.

- *We thank the reviewer for this comment. The part "examples" should not be in the text as the decision was to focus on labels and definitions. We have noew changed it.*

Can the sentences "Additionally, in accordance with ontological best practice, BCTs that refer to two separate techniques within the same definition should be separated out, for example, 'problem solving' should be 'problem solving BCT' and 'prompt problem solving BCT'."(p.7) be clarified? Does this suggest that using problem solving as a BCT is a separate technique from prompting the use of problem solving?

- *Yes, it means they are two separate BCTs. To clarify, we changed the sentence as follows: "Additionally, in accordance with ontological best practice, existing BCTs in the BCTTv1 that refer to more than one technique in their definition should be separated into more than*

one BCT. For example, the BCT in the BCTTv1 "problem solving" should be "problem solving BCT" (referring to person analysing factors influencing the behaviour and generating and selecting strategies to overcome barriers) and "prompt problem solving BCT" (referring to the source prompting the person to analyse factors influencing the behaviour and generating and selecting strategies to overcome barriers with the person)."

Competing Interests: No competing interests were disclosed.

Reviewer Report 11 October 2022

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Chris Keyworth
Manchester Centre for Health Psychology, Division of Psychology and Mental Health, University of Manchester, Manchester, UK

Thank you for the invitation to review this paper aiming to gather data to inform the development of BCTTv1 into a more elaborated knowledge structure (an ontology). This is an important piece of work and will be valuable in informing future developments of the BCTT and ontology. I enjoyed reading the paper and can see the value of the work for informing future research, policy and practice. Although the data gathered does not include a systematic search of the literature (which the authors acknowledge), a strength of this work is the triangulation approach, in gathering a wide range of sources and gaining extensive feedback.

There are some points below which I feel would strengthen the manuscript, particularly around the methods/analysis used to synthesise the data.

- Minor point – abstract – isn't clear what the final sentence of the results is referring to. Perhaps just a little refinement to say recommendations for improving the taxonomy? The three items presented also don't make sense in isolation. There are some good examples throughout the paper where this is much clearer (see points below).

- Intro – for the lay reader, can you say what the "16 higher-order groupings" refer to and maybe provide an example? This is a little broad at present. E.g., overarching theme of each group – group 1 refers to goals and planning. I suspect this paper is going to be read very widely read by a number of different audiences, some of whom won't be familiar with the terminology.

- "The BCTTv1 was developed over an iterative programme of research studies" – would some dates be helpful for historical context? Could use data from Table 1.

- At first mention of the Behaviour Change Wheel Framework – could you very briefly describe the framework and its foundations – i.e., synthesis of 19 frameworks, allows researchers to make recommendations for policy etc.

- "…is being developed as part of the Human Behaviour-Change (Michie et al., 2017; Michie et al., 2021) – I think the word "project" might be missing here?

- Same paragraph, could "source" be changed to "source of the intervention"? Does it also need something like "i.e., who delivers the intervention"? Also perhaps amend to "intervention setting" instead of just "setting" for extra clarity.

- Are there any examples of "artificial-intelligence based methods" that you could cite? Is data mining an example?

- The aims could be a little clearer here and perhaps in the abstract also. For example, there are at least two aims which could be more explicit: 1) to gather data to update BCTTv1 and convert it into a BCT ontology, and 2) provide recommendations for …. (this bit isn't immediately clear and could be more explicit) – gather data to inform the BCT ontology? Same comment applies to the abstract.

- I really like the first section of the design and sample section – clear and explicitly outlining the main aims of the study. Can this be used to address the point about making the study aims explicit?

- Methods - typo at top of p4 - any use of – should be user.

- Sentence starting "The feedback…" is a tad long and difficult to follow. Could you rework? This should improve the clarity.

- In stage two (the evidence synthesis) there could be more methodological detail added here. What type of coding was done? Did the two coders review each source independently, then agree upon the final code? Any inter-rater reliability? I'm also not sure how the categories were derived. Some clarity in the sentence mentioned above should help.

- Paragraph under stage three is good – I like the clear definitions that are presented.

- The sentence "The number of users that contributed to each feedback source ranged from 22 to 105." Would be better suited in the paragraph above.

- Under additional BCTs it would be good to know a little more about the 22 additional BCTs. It left me intrigued wondering what the new suggestions were. I understand this will be covered in more detail in the next paper, but is there anything at all you can say about what the extra ones were? Or which higher order groupings they belonged to? It would be interesting to know which if the higher order groupings the suggestions belonged to.

- In the labels or definitions of BCTs, I like the examples that are provided. These will definitely help the lay reader. I was a little unclear what table 5 was referring to? Is this the number of suggestions about amending a BCT label, definition, or adding an example? Or

all of them?

- Like the description of Amendments to BCTTv1 groupings. I also like the frequently reported issues with illustrative quotes. Should this section come before “Amendments to BCTTv1 groupings” as the quotes are about labels and definitions?

- The section “Stage three: Recommendations for ontology development” is clear and I like the three clear recommendations.

- Use of BCIO acronym could be consistent throughout the paper – is referred to as “BCI ontology” in the discussion.

Thanks for the opportunity to review this important work. I hope you find the comments useful.

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?
Partly

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?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Behaviour change

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Marta Marques, NOVA Medical School|Faculdade de Ciências Médicas (NMS|FCM,) Universidade Nova de Lisboa, Lisboa, Portugal., Portugal

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BCTT and ontology. I enjoyed reading the paper and can see the value of the work for informing future research, policy and practice. Although the data gathered does not include a systematic search of the literature (which the authors acknowledge), a strength of this work is the triangulation approach, in gathering a wide range of sources and gaining extensive feedback. ***We thank the reviewer for the positive feedback about this paper. All comments made by the reviewer were addressed.***

There are some points below which I feel would strengthen the manuscript, particularly around the methods/analysis used to synthesise the data.

- Minor point – abstract – isn't clear what the final sentence of the results is referring to. Perhaps just a little refinement to say recommendations for improving the taxonomy? The three items presented also don't make sense in isolation. There are some good examples throughout the paper where this is much clearer (see points below).

As suggested, we changed the sentence as following: "Three recommendations <u>to improve the</u> BCTTv1 resulted from this analysis: to review the label and definition of each BCT, the 16 groupings of BCTs, and the examples illustrating BCTs.

- Intro – for the lay reader, can you say what the "16 higher-order groupings" refer to and maybe provide an example? This is a little broad at present. E.g., overarching theme of each group – group 1 refers to goals and planning. I suspect this paper is going to be read very widely read by a number of different audiences, some of whom won't be familiar with the terminology.

For ease of reading and as suggested by the reviewer. we have changed the sentence to: "The Behaviour Change Techniques Taxonomy v1 (BCTT v1) (Michie *et al.,* 2013) is the most widely used classification of BCTs. The BCTTv1 provides a list of 93 clearly labelled and defined BCTs, organised in 16 higher-order groupings representing the function of the BCTs in each group, e.g. group 1 refers to goals and planning BCTs.

- "The BCTTv1 was developed over an iterative programme of research studies" – would some dates be helpful for historical context? Could use data from Table 1.

Table 1 refers to the feedback of the BCTTv1 that was conducted as part of the current study, while the sentence mentioned refers to the process of the development of the BCTTv1 which is described in detail in the reference now provided (Michie et al., 2015). We hope this is clearer now.

- At first mention of the Behaviour Change Wheel Framework – could you very briefly describe the framework and its foundations – i.e., synthesis of 19 frameworks, allows researchers to make recommendations for policy etc.

As suggested, we have added a sentence briefly describing the framework, as follows: "The Behaviour Change Wheel is an integrative framework that derived from a synthesis of 19 frameworks to aid the systematic development and evaluation of behaviour change interventions and has been used across a wide range of behaviours and to inform policy (West et al., 2020). The framework provides a systematic way of identifying i. the problem in behavioural terms, ii. what needs to change for the target behaviour to change in terms of capabilities, opportunities and motivation (COM-B model), iii. the relevant intervention functions and techniques to change the target behaviour, and iv. the relevant policy categories (societal or organizational strategies) for implementing sustained behavioural changes."

- "…is being developed as part of the Human Behaviour-Change (Michie et al., 2017; Michie et al., 2021) – I think the word "project" might be missing here?

We thank the reviewer for noticing this. We have added the word "project".

- Same paragraph, could “source” be changed to “source of the intervention”? Does it also need something like “i.e., who delivers the intervention”? Also perhaps amend to “intervention setting” instead of just “setting” for extra clarity.

As recommended by the reviewer we have changed the sentence as follows: " The BCIO consists of an upper level with 42 entities, specifying features of behaviour change interventions, such as mode of delivery (Marques et al., 2021), source of the intervention (Norris et al., 2021), and the setting where the intervention takes place (Norris et al., 2020). One of the entities in the BCIO is BCT , specified as part of the content in a given behaviour change intervention scenario (Michie et al., 2021)."

- Are there any examples of “artificial-intelligence based methods” that you could cite? Is data mining an example?

We added two examples between brackets "(e.g. natural language processing, machine learning)"

- The aims could be a little clearer here and perhaps in the abstract also. For example, there are at least two aims which could be more explicit: 1) to gather data to update BCTTv1 and convert it into a BCT ontology, and 2) provide recommendations for …. (this bit isn’t immediately clear and could be more explicit) – gather data to inform the BCT ontology? Same comment applies to the abstract.

Reviewer 2 also suggested changes to the aims, namely that the recommendations for its development into an ontology should be a secondary aim. We have therefore revised that section as follows: The primary aim of this study was to gather data with which to update the BCTTv1. This paper reports an analysis of feedback about BCTTv1 from experts and intervention developers from a variety of fields. Feedback was sought on the limitations and associated improvements that could be made to BCTTv1. The latter included in relation to adding BCTs, improving BCT labels and definitions, and changing groupings and structure. Recommendations for developing the BCTTv1 into a BCT Ontology are made based on the feedback." We also changed the abstract to:" This study aimed to gather data to improve the BCTTv1 and provide recommendations for developing it into a more elaborated knowledge structure, an ontology."

- I really like the first section of the design and sample section – clear and explicitly outlining the main aims of the study. Can this be used to address the point about making the study aims explicit?

We thank the reviewer for the suggestion. We have already improved the aims as explained in the previous comments.

- Methods - typo at top of p4 - any use of – should be user.

Thank you for noticing the typo, we have amended it.

- Sentence starting “The feedback…” is a tad long and difficult to follow. Could you rework? This should improve the clarity.

We have revised as follows: " Data from each source of feedback relating to the BCTTv1 were reviewed by two authors (EC and MM). A content analysis was performed on the data collected from the BCTTv1 user survey (EC). Four main categories were formed based on the main issues raised: additional BCTs, amendments to labels or definitions of BCTs, amendments to the BCT groupings, and general improvements. Two authors (EC and MM) used these categories to code the remaining sources of feedback jointly (via online meetings). As this process was undertaken jointly, no interrater reliability data was produced".

- In stage two (the evidence synthesis) there could be more methodological detail added here. What type of coding was done? Did the two coders review each source

independently, then agree upon the final code? Any inter-rater reliability? I'm also not sure how the categories were derived. Some clarity in the sentence mentioned above should help.

We have provided more methodological detail in this section as follows: "Data from each source of feedback relating to the BCTTv1 were reviewed by two authors (EC and MM). A content analysis was performed on the data collected from the BCTTv1 user survey (EC). Four main categories were formed based on the main issues raised: additional BCTs, amendments to labels or definitions of BCTs, amendments to the BCT groupings, and general improvements. Two authors (EC and MM) used these categories to code the remaining sources of feedback jointly (via online meetings). As this process was undertaken jointly, no interrater reliability data was produced".

- Paragraph under stage three is good – I like the clear definitions that are presented.

Thank you for the positive feedback.

- The sentence "The number of users that contributed to each feedback source ranged from 22 to 105." Would be better suited in the paragraph above.

We agree, and have moved the sentence to the previous paragraph.

- Under additional BCTs it would be good to know a little more about the 22 additional BCTs. It left me intrigued wondering what the new suggestions were. I understand this will be covered in more detail in the next paper, but is there anything at all you can say about what the extra ones were? Or which higher order groupings they belonged to? It would be interesting to know which if the higher order groupings the suggestions belonged to.

Review by the research team resulted in 22 suggestions for new BCTs. These suggestions, along with corresponding relationships are to be further developed in an ontology of BCTs.

- In the labels or definitions of BCTs, I like the examples that are provided. These will definitely help the lay reader. I was a little unclear what table 5 was referring to? Is this the number of suggestions about amending a BCT label, definition, or adding an example? Or all of them?

We are glad the examples were considered helpful. Table 5 refers to number of suggestions to amend either the BCT label, definition or example as stated in the text. We have changed the title of the table to make it clearer, as follows: "Number of suggestions made related to the label, definition or example of specific behaviour change techniques (BCTs)."

- Like the description of Amendments to BCTTv1 groupings. I also like the frequently reported issues with illustrative quotes. Should this section come before "Amendments to BCTTv1 groupings" as the quotes are about labels and definitions?

We have changed the order as suggested by the reviewer.

- The section "Stage three: Recommendations for ontology development" is clear and I like the three clear recommendations.

Thank you for the positive feedback.

- Use of BCIO acronym could be consistent throughout the paper – is referred to as "BCI ontology" in the discussion.

We have revised and amended throughout the text. Thanks for the opportunity to review this important work. I hope you find the comments useful. *The comments were really hepful. Thank you for the reiview*

Competing Interests: No competing interests were disclosed.