RESEARCH ARTICLE

REVISED Linking behaviour change techniques to mechanisms of action: Using the Theory and Techniques Tool alongside the Behaviour Change Intervention Ontology

[version 2; peer review: 3 approved]

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Abstract

Background

Understanding how interventions work requires clear hypotheses, rigorous testing, and accurate reporting of links between behaviour change techniques (BCTs)—the smallest replicable active components of interventions—and mechanisms of action (MoAs), the processes through which behaviour changes. The Theory and Techniques Tool (TaTT) provides a grid of likely BCT-MoA links to guide intervention design, based on literature synthesis and expert consensus. Recently, the Behaviour Change Intervention Ontology development team introduced detailed, computer-readable lower-level ontologies for BCTs and MoAs, but limited guidance exists on integrating the BCT-MoA links proposed by the TaTT with these ontologies. This study aimed to map BCTs and MoAs from the TaTT to corresponding classes (i.e., categorisations or groupings) in the Behaviour Change Technique Ontology (BCTO) and Mechanism of Action (MoA) Ontology.

Methods

Three researchers mapped the classes from the BCTO onto 74 BCTs

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within the TaTT, using their definitions. Similarly, two researchers mapped classes from the MoA Ontology onto the 26 MoAs within the TaTT. Discrepancies were resolved through discussion with senior researchers. Subsequent updates to the BCT and MoA Ontologies necessitated a researcher updating the mappings, with the revisions being verified by the research team.

Results

From the BCTO, 85 BCTs were mapped to the 74 BCTs present in the TaTT, while 56 MoAs from the MoA Ontology were mapped to the 26 MoAs present in the TaTT. Subclasses of these 85 BCTs and 56 MoAs provide additional specificity and can be found by further engaging with these ontologies.

Discussion

Mapping the TaTT to the Behaviour Change Intervention Ontology enhances clarity and precision in selecting and reporting BCT-MoA links, enabling integration of data across frameworks. Future work should maintain these mappings as ontologies evolve and users provide more feedback and evidence on BCTs, MoAs and their links, ensuring they remain relevant and user-friendly.

Plain language summary

Understanding how interventions change people's behaviours is important for making them more effective. Behaviour change interventions include specific actions called "behaviour change techniques" ("BCTs"), such as encouraging people to set goals for their behaviour. These BCTs are the "active ingredients" of interventions that can be observed and repeated. BCTs work by affecting processes called mechanisms of action (MoAs), i.e. how the intervention leads to change. For example, MoAs might involve changing a person's beliefs, improving their abilities, or increasing their access to resources.

To support intervention developers in selecting BCTs to target specific MoAs, an online resource, called the Theory and Technique Tool (TaTT), was previously developed. This tool provides an evidence-based grid showing which BCTs are likely or unlikely to change certain MoAs. Recently, new tools—the Behaviour Change Technique Ontology (BCTO) and Mechanisms of Action Ontology (MoA Ontology)—were developed to include a wider range of BCTs and MoAs and provide more precise and computer-readable BCT and MoA definitions. By aligning the TaTT with these newer tools, we can support (1) ontology users in hypothesising about likely BCT-MoA links, and (2) TaTT users in identifying more detailed yet relevant BCTs and MoAs from the ontologies and using these in computer applications.

This study aimed to map the newer ontologies' categories to the

TaTT's 74 BCTs and 26 MoAs. Researchers carefully compared and discussed definitions from both tools to create mappings. The study found that 85 BCTs in the newer ontology corresponded to 74 BCTs from the TaTT, and 56 MoAs in the newer ontology corresponded to 26 MoAs from the TaTT.

By linking the ontologies to the TaTT, this work makes it easier to use these tools together. This helps design and report behaviour change interventions more clearly and supports advanced uses like automated data analysis.

Keywords
behaviour change; intervention; ontology; theory; mechanisms of action; behaviour change techniques

This article is included in the Human Behaviour-Change Project (including the APRICOT project) gateway.

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Competing interests: Robert West undertakes paid training and consultancy for Everyone Health, a company that is commissioned by English local government to support people to change their behaviour to improve their health. He undertakes paid consultancy for Godot, a Japanese-based company that harnesses AI in support of behaviour change to improve wellbeing, Qnovia a company that is developing a novel nicotine inhalation device to aid smoking cessation, and Public Health Wales' Behavioural Insights Team. He is an unpaid director of the Unlocking Behaviour Change Community Interest Company. He is an unpaid member of the Scientific Advisory Board of the Smoke Free mobile application. Susan Michie undertakes paid consultancy for Godot, a Japanese-based company that harnesses AI in support of behaviour change to improve wellbeing, and is an unpaid director of the Unlocking Behaviour Change Community Interest Company.

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REVISED **Amendments from Version 1**

This version of the manuscript includes updates made in response to the feedback from the two peer reviewers, including (1) clarifications to the Introduction, (2) updates to the Methods section to reflect the most up-to-date versions of the Behaviour Change Technique (BCT) Ontology and the Mechanism of Action (MoA) Ontology, and a clearer description of the mapping between the MoA Ontology and the Theory and Techniques Tool (TaTT), (3) explicit mention of TaTT BCTs and MoAs included as cross-references or examples in the respective ontologies, where one-to-one mappings with ontology classes exist, (4) a minor refinement to the mapping of the MoA Ontology to the TaTT, explaining the mapping to the TaTT MoA 'Optimism' and (5) minor updates to the references.

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

Table of acronyms

Acronym	Meaning
BCIO	Behaviour Change Intervention Ontology
BCIOSearch	Behaviour Change Intervention Ontology Search Tool
BCT	Behaviour Change Technique
BCTO	Behaviour Change Technique Ontology
BCTTv1	Behaviour Change Technique Taxonomy V1
HBCP	Human Behaviour Change Project
MoA	Mechanisms of Action
TaTT	Theory and Techniques Tool

Introduction

Behaviour change interventions have the potential to address critical policy areas, such as health and sustainability, by influencing relevant behaviours (Albarracín *et al.*, 2024; Michie & West, 2013; Newell *et al.*, 2021). However, these interventions often show mixed effectiveness at changing target behaviours (Jepson *et al.*, 2010; Johnson & May, 2015). To improve intervention effectiveness, established guidance on developing and evaluating interventions, such as the UK Medical Research Council Framework, advocate the use of ***theory*** to inform interventions (Craig *et al.*, 2008; Skivington *et al.*, 2021) (see glossary of bold, italicised terms in Table 1). Theories have various roles in supporting intervention design, which include helping:

- identify ***mechanisms of action (MoAs***; the processes through which interventions bring about their influence on behaviour) to understand causal processes behind interventions (Michie *et al.*, 2008)
- identify important, relevant and feasible outcomes that an intervention intends to target (Davidoff *et al.*, 2015)
- inform the content and delivery of an intervention (O'Cathain *et al.*, 2019)
- reduce research waste by summarising the current state of knowledge, providing a framework to falsify incorrect assumptions and facilitate accumulation of evidence, and guiding future research (Davidoff *et al.*, 2015; Gardner *et al.*, 2010; Lippke & Ziegelmann, 2008)

Specifically, by supporting intervention designers to select, target and test their interventions' MoAs (e.g., motivation, capability or opportunity), theories support our understanding of how interventions work and thereby can inform future intervention designs (Carey *et al.*, 2019; Michie *et al.*, 2018; Schenk *et al.*, 2024). For example, various theories propose 'self-efficacy belief' to be an important ***theoretical construct*** for changing behaviours (Bandura, 1997; Locke & Latham, 1990; Luszczynska & Schwarzer, 2015; Rosenstock, 1974), and based on this, intervention designers can hypothesise self-efficacy as an MoA in their own intervention and test or further explore it. A representation of how interventions work through MoAs to change behaviours is shown in Figure 1. As part of interventions, ***behaviour change techniques (BCTs)*** can be used to target MoAs. BCTs have been defined as "*a part of the content of a behaviour change intervention that are observable, replicable and on their own have the potential to bring about behaviour change*" (Marques *et al.*, 2024b, p., 8). An example of a link between a BCT and MoA would be: Altering a participants' environment (BCT) which changes the participants' opportunities (MoA) to enact a behaviour. While MoAs are processes through which interventions work to change behaviour, we often refer to states or dispositions (e.g., beliefs rather than changing or maintaining beliefs) as MoAs in behavioural sciences. In this paper, we use similar language for brevity, but each time we refer to an MoA, it should be understood as either an MoA or a key construct that can be influenced and is part of an intervention's MoA.

Despite calls for increased and better use of theories, many intervention reports lack explicit and clear descriptions of how theories were used during intervention development and evaluation (Dalgetty *et al.*, 2019; Mama *et al.*, 2015; Prestwich *et al.*, 2014; Prestwich *et al.*, 2015). This includes poor reporting of the links between intervention components (e.g., BCTs) and specific theoretical constructs (including potential MoAs). For example, a meta-analysis found that only half the included studies explicitly reported a theory base, and of these, 90% did not report links between the BCTs used with specific theoretical constructs (Prestwich *et al.*, 2014). This lack of reporting may, in part, stem from researchers having to navigate an increasingly complex theoretical landscape, with over 80 behavioural theories, many of which do not explicitly link BCTs to potential MoAs (Davis *et al.*, 2015; Michie *et al.*, 2008).

The Theory and Techniques Tool

To provide practical guidance on selecting BCTs to target potential MoAs in interventions, an online evidence-based grid that shows 'likely' BCT-MoA links[1], the ***Theory and***

[1] A 'likely' BCT-MoA link refers to a link that (1) is explicitly hypothesised or identified in the literature and (2) agreed upon by behavioural experts to exist (i.e., that the BCT changes behaviour through the MoA), and was identified through the triangulation of evidence in the literature and an expert consensus study (Johnston *et al.*, 2018).

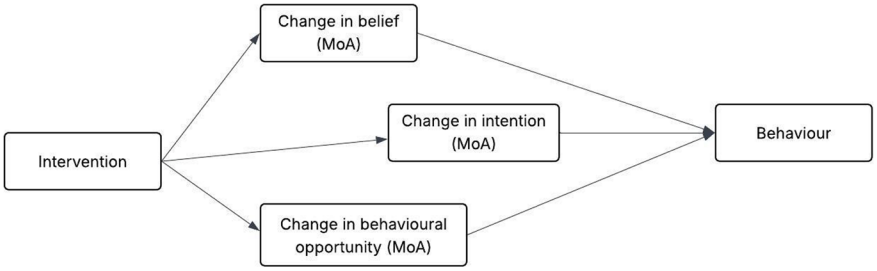

Figure 1. Representation of an example link between intervention, its MoAs and target behaviour. This figure has been reproduced with permission from Schenk *et al.* (2024).

Technique Tool (TaTT), was developed. These links were between 74 BCTs selected from the 93 BCTs of the Behaviour Change Techniques Taxonomy v1 (BCTTv1; Michie *et al.*, 2013) and 26 potential MoAs. The 74 BCTs were the most commonly occurring ones, from the 93 BCTs, in a literature review (Carey *et al.*, 2019). The 26 MoAs included 14 MoAs from the Theoretical Domains Framework (Cane *et al.*, 2012) and 12 frequently occurring MoAs[2] identified from 83 behaviour change theories (Davis *et al.*, 2015). Figure 2 shows a screenshot of the TaTT, with the red box on the left-hand side showing some of the 74 BCTs, and the horizontal red box showing the abbreviated labels of some of the 26 MoAs in this tool. The labels and definitions for these 74 BCTs and 26 MoAs can be found in Table 2 and Table 3.

To generate the BCT-MoA links in the TaTT, three studies were conducted (Carey *et al.*, 2019; Connell *et al.*, 2019; Johnston *et al.*, 2018). The first study was a literature synthesis that identified links between BCTs and MoAs in published intervention reports (Carey *et al.*, 2019), while the second was an expert consensus study where behaviour change experts rated BCT-MoA links (Connell *et al.*, 2019). A link was made when intervention reports included descriptions explicitly hypothesising that the BCT changes behaviour through the MoA, or behaviour change experts agreed that the BCT changed behaviour via the MoA. To triangulate these findings, a third study examined the concordance of links and reconciled discrepancies between these two sources of evidence (Johnston *et al.*, 2021). This triangulation proposed an evidence-based grid (a heat map) presenting links between 74 BCTs and 26 MoAs, which was made available in an online interactive platform (https://theoryandtechniquetool.humanbehaviourchange.org/). The heat map contains 1924 cells (for every possible BCT-MoA link variation), with each cell colour coded indicating either a link (green), non-link (blue), inconclusive (yellow), or lack of evidence (white) (see Figure 3). For example, in Figure 3, the red boxes signpost the BCT "1.2 Problem Solving" and the MoA "BaCa", which stands for the "Belief about Capabilities", while the green box in the grid indicates a link between this BCT and MoA. Clicking on any cell reveals the meta-data about the relevant link from the three studies. However, for precise information on evidence regarding the links, the original studies should be referred to (Carey *et al.*, 2019; Connell *et al.*, 2019; Johnston *et al.*, 2018; Johnston *et al.*, 2021).

The TaTT can be used for several purposes, notably to:

- Identify evidence-based 'likely' BCT-MoA links to inform intervention development and evaluations
- Allow users to link BCTs in interventions, selected without an explicit basis in behaviour change theory, to the MoAs they likely target, facilitating these BCT-MoA links to be investigated and tested in future studies
- Maximise the rate of scientific advance by sharing data and knowledge as easily and efficiently as possible, by allowing users to submit new evidence to the tool about links.

The Behaviour Change Technique Ontology and Mechanism of Action Ontology

Since the first release of the TaTT in 2018, there have been advances in structures for conceptualising and specifying behaviour change interventions, through the development of ***ontologies*** (National Academies of Sciences, 2022). Ontologies are formal structures that represent knowledge within a domain in terms of uniquely specified ***classes*** of ***entities*** and ***relationships*** between them (Arp *et al.*, 2015; Hastings, 2017). An important feature of ontologies is that every class and type of relation between classes is given a unique ID in the form of a ***Uniform Resource Identifier*** (commonly referred to as ***URI***). This computational structure allows ontologies to be "read" by computers (Arp *et al.*, 2015; He *et al.*, 2018; Seppälä *et al.*, 2014); we can then use artificial intelligence approaches for automated processing of information, such as for evidence synthesis or predicting outcomes (Hastings *et al.*, 2023; West *et al.*, 2024). Ontologies offer important benefits to advancing science. They facilitate:

- the accumulation of knowledge through interoperability (linking classes across domains and datasets) (Baird *et al.*, 2023; Hastings *et al.*, 2024)

[2] These 12 MoAs were identified by first judging which constructs from the 83 theories qualified as MoAs and then grouping the same and very similar MoAs together (Schenk *et al.*, 2024). The most frequently occurring MoAs (i.e., the groups with the highest number of MoAs) were identified and compared to the 14 domains (potential MoAs) of the Theoretical Domains Framework (Cane *et al.*, 2012). The 12 most frequently occurring groups, which were not covered by the Theoretical Domains Framework, were included in the 26 MoAs for the TaTT. It should be noted that the complete list of theoretical constructs (from the 83 theories) also served as starting point for the MoA Ontology, but additional work was done to more precisely capture relevant constructs as MoAs and structure them within the ontology (Schenk *et al.*, 2024)

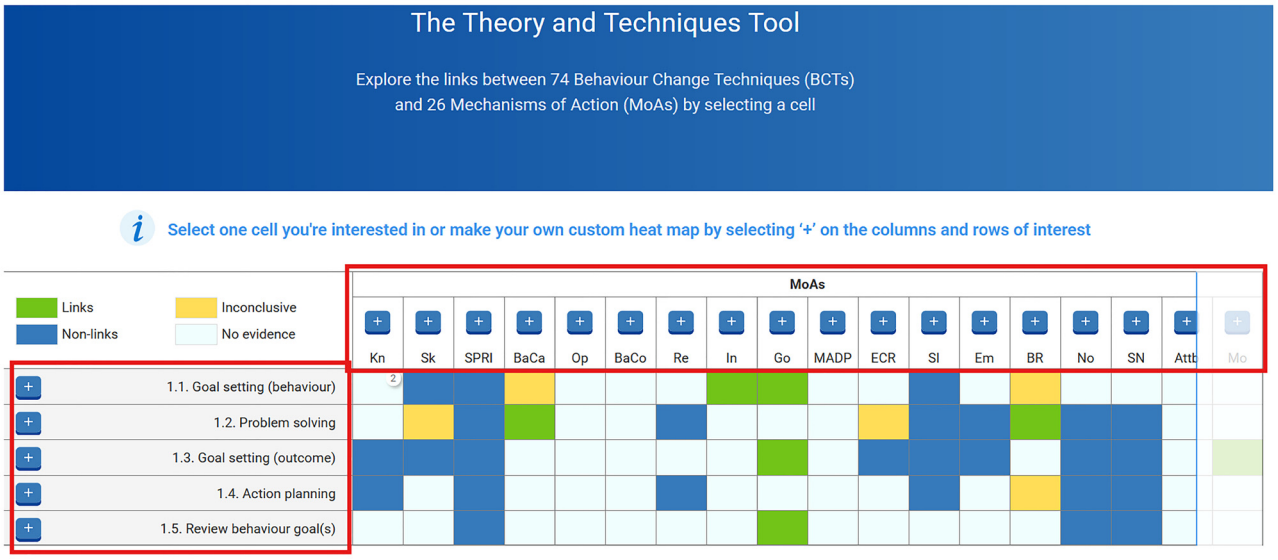

Figure 2. Screenshot of the Theory and Technique Tool (TaTT).

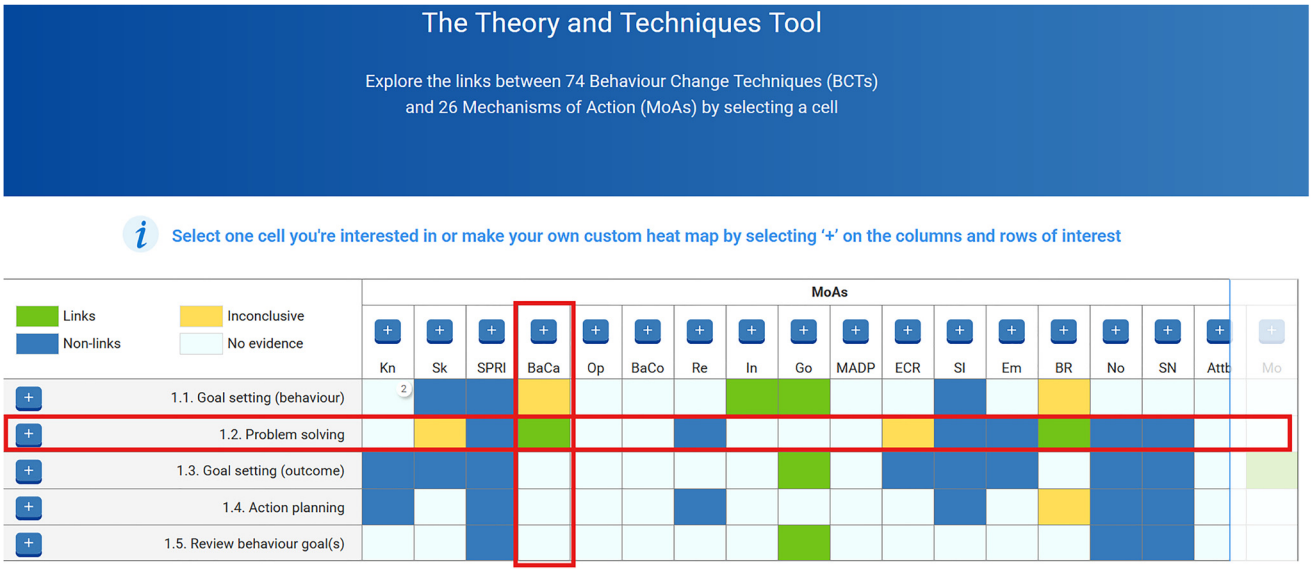

Figure 3. Screenshot of the Theory and Technique Tool (TaTT), with a BCT and MoA link highlighted.

- more efficient information retrieval, data integration and data sharing (Chen *et al.*, 2010; Hastings *et al.*, 2011)
- communication and collaboration across domains (Gene Ontology Consortium, 2015; Sharp *et al.*, 2023)

The development and use of ontologies in the behavioural and social sciences is growing (Norris *et al.*, 2019; Sharp *et al.*, 2023). Most notably, the Behaviour Change Intervention Ontology (BCIO) has been recognised as an example of a detailed and precise ontology that is characterised by strong semantics (National Academies of Sciences, 2022). The BCIO characterises behaviour change interventions, their MoAs, outcome behaviours, as well as engagement with interventions and intervention contexts, and the evaluations of interventions (see Figure 4; Michie *et al.*, 2020). Figure 4 is a simplified schematic representation of the BCIO's upper level, with upper-level classes shown in the white boxes. Each of these upper-level classes capture one or more ***lower-level ontologies*** part of the BCIO; these lower-level ontologies are signposted in the blue boxes,

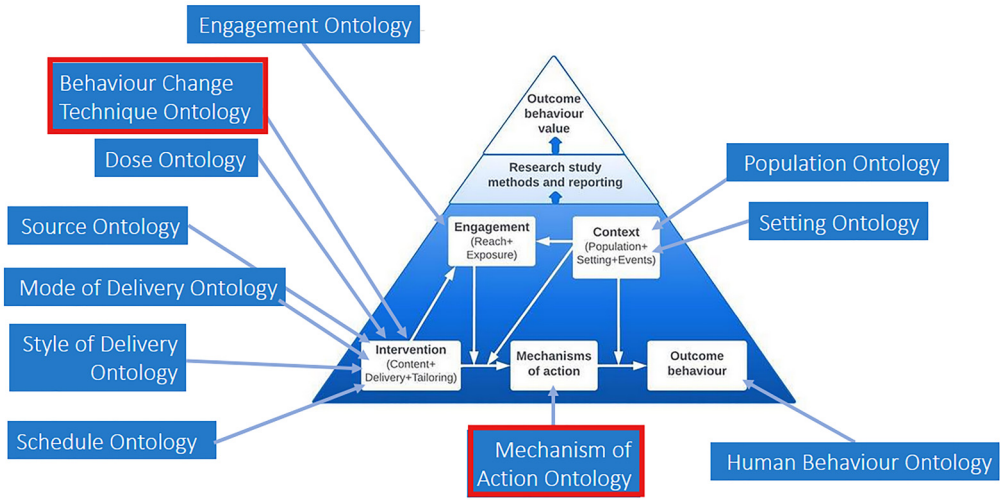

Figure 4. Schematic of the upper-level BCIO and its lower-level ontologies, with the red boxes around the Behaviour Change Technique Ontology (BCTO) and the Mechanism of Action (MoA) Ontology.

with the arrows indicating which broad class they relate to. For example, the box for "Intervention" captures an ontology for BCTs (called the ***Behaviour Change Techniques Ontology [BCTO])*** (Marques *et al.*, 2024b), as well as other ontologies for delivery, while the box for "Mechanism of action" captures the ***Mechanism of Action (MoA) Ontology*** (Schenk *et al.*, 2024).

The links in the TaTT links relate to two classes within the upper-level BCIO and their relevant ontologies: BCTO and MoA Ontology (as shown in Figure 4). BCTO extends the BCTTv1 into a formal ontology (Corker *et al.*, 2023; Marques *et al.*, 2024b), including most recently 285 BCTs. The Mechanism of Action Ontology (Schenk *et al.*, 2024) specifies the potential processes of change in behaviour change interventions (potential MoAs) and includes 622 classes (last reported as 284 classes in Schenk *et al.* [2024]), following an update informed by a recent mapping exercise of the BCIO to behavioural theories and issues that have been addressed on the ontology's issue tracker on GitHub (https://github.com/Human-BehaviourChangeProject/ontologies/issues). Ontologies will continue to evolve in response to new evidence and feedback (He *et al.*, 2018), and the number of classes may increase in the future. The most up-to-date version of these ontologies can always be found and downloaded from the Human Behaviour-Change Project repository on ***GitHub*** : https://github.com/Human-BehaviourChangeProject/ontologies

Why align the TaTT with the BCTO and MoA Ontologies?

By using the TaTT alongside the BCTO and MoA Ontologies, researchers and practitioners could hypothesise potential links between the extended number of BCTs and MoAs in these ontologies. For example, starting with the ontology class for "self-efficacy belief for a behaviour" (alphanumeric ID: BCIO:006154), ontology users could explore potential links to BCTs through the TaTT, in this case looking at the links of the TaTT MoA "Belief about Capabilities". A mapping between these tools can provide explicit guidance about how these tools could be used together and integrated.

Researchers and practitioners, who use the TaTT, could use a mapping to the ontologies to identify and report the more detailed, clearly defined ontology classes in their protocols and papers. In addition, the unique alphanumeric identifier (e.g. BCIO:006154) attached to each class allows data to be computer-readable, and thus enables further computational analysis (Hastings, 2017; Matentzoglu *et al.*, 2022). For example, TaTT users could start off by identifying a TaTT MoA (e.g., "Memory, attention and decision process") and then the corresponding detailed ontology classes for the potential MoA of interest (e.g., using the "memory process" class to specify the MoA more granularly where relevant). This would allow them to report more nuanced and varied evidence about BCT-MoA links or lack thereof. While ontologies facilitate being explicit and transparent about conceptual definitions, the BCTO and MoA Ontology are much more complex and time consuming to engage with than the TaTT. For TaTT users, a mapping to the ontologies can help them familiarise themselves with these new tools, without needing to immediately engage with the detailed ontologies.

Finally, an explicit mapping between the TaTT and ontologies will help users link and integrate evidence from studies using these two frameworks, thereby potentially feeding into a shared evidence base about behaviour change. In the future, this alignment could enable evidence accumulated with the TaTT to be used in machine learning applications, drawing on the computer-readable classes of the BCTO and MoA Ontology.

Aim

This study aimed to create a mapping of the TaTT and the BCIO, in order for these tools to become more aligned for use in intervention development and evaluation. To achieve this, we mapped (1) the classes from the BCTO to one or more corresponding BCTs in the TaTT, and (2) the classes from the MoA Ontology to their corresponding MoAs in the TaTT.

Table 1. Glossary of terms (Marques *et al.*, 2024b; Michie *et al.*, 2017; Schenk *et al.*, 2024).

Term	Definition	Source
Behaviour change technique	A planned process that is the smallest part of BCI content that is observable, replicable and on its own has the potential to bring about behaviour change.	(Marques *et al.*, 2024b)
Behaviour Change Technique Ontology	A lower-level ontology of the Behaviour Change Intervention Ontology, which includes classes for BCTs, with clear labels, definitions and computer-readable alphanumeric IDs (URIs), and specifies relationships between these classes.	(Marques *et al.*, 2024b)
Class	Classes in ontologies represent types of entities in the world. The terms "entity" and "class" can be used interchangeably to refer to the entities represented in an ontology. Classes can be arranged hierarchically by the specification of parent and child classes; see definition of parent class in the glossary	Arp *et al.* (2015)
Entity	Anything that exists, including objects, processes, and their attributes.	Arp *et al.* (2015)
GitHub	A web-based platform used as a repository for sharing code, allowing version control.	https://github.com/
Mechanism of action	A process that is causally active in the relationship between a Behaviour Change Intervention scenario and its outcome behaviour.	Schenk *et al.* (2024)
Mechanism of Action Ontology	A lower-level ontology of the Behaviour Change Intervention Ontology, which includes classes for MoAs, with clear labels, definitions and computer-readable alphanumeric IDs (URIs), and specifies relationships between these classes.	Schenk *et al.* (2024)
Ontology	A standardised representational framework providing a set of classes 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 classes (subclasses) 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)
Relationship	The manner in which two classes are connected or linked.	Arp *et al.* (2015)
Lower-level ontology	A part of a broader ontology, which captures classes and relationships that fall within a specific discrete scope. Also referred to as "lower-level ontology".	Sari *et al.* (2013)
Theory	A set of constructs and/or statements that describe, explain and predict phenomena.	Davis *et al.* (2015)
Theoretical construct	A concept proposed within a theory.	Michie *et al.* (2005)
Theory and Technique Tool	An online interactive tool that includes an evidence-based grid of 'likely' links between BCTs and MoAs.	https://theoryandtechniquetool.humanbehaviourchange.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

Methods

This study involved two steps: (1) mapping the BCTs (classes) from the BCTO (Marques *et al.*, 2024b) to the 74 BCTs in the TaTT (Johnston *et al.*, 2021) and (2) mapping MoAs (classes) from the MoA Ontology (Schenk *et al.*, 2024) to the 26 MoAs in the TaTT (Johnston *et al.*, 2021). Figure 5 shows an overview of this process.

Step 1: Mapping the BCTs from the BCTO to the TaTT

Three researchers (AW, MM, LZ) independently reviewed the 281 class labels and definitions in BCTO (published in May, 2024; see this version in https://osf.io/ya74q), judging and recording which classes were represented by each of the 74 BCTs in the TaTT (https://theoryandtechniquetool.humanbehaviourchange.org/tool). For a class to be considered captured by a TaTT BCT, it needed to either (1) have a definition with the same meaning (a one-to-one match) or (2) include all the attributes of the BCT while providing more specific detail. In cases where a class did not align with a single TaTT BCT, the researchers recorded multiple TaTT BCTs for the class, as needed. They then compared their records, discussed any disagreements, and reconciled differences to finalise the mappings for the BCTs. The

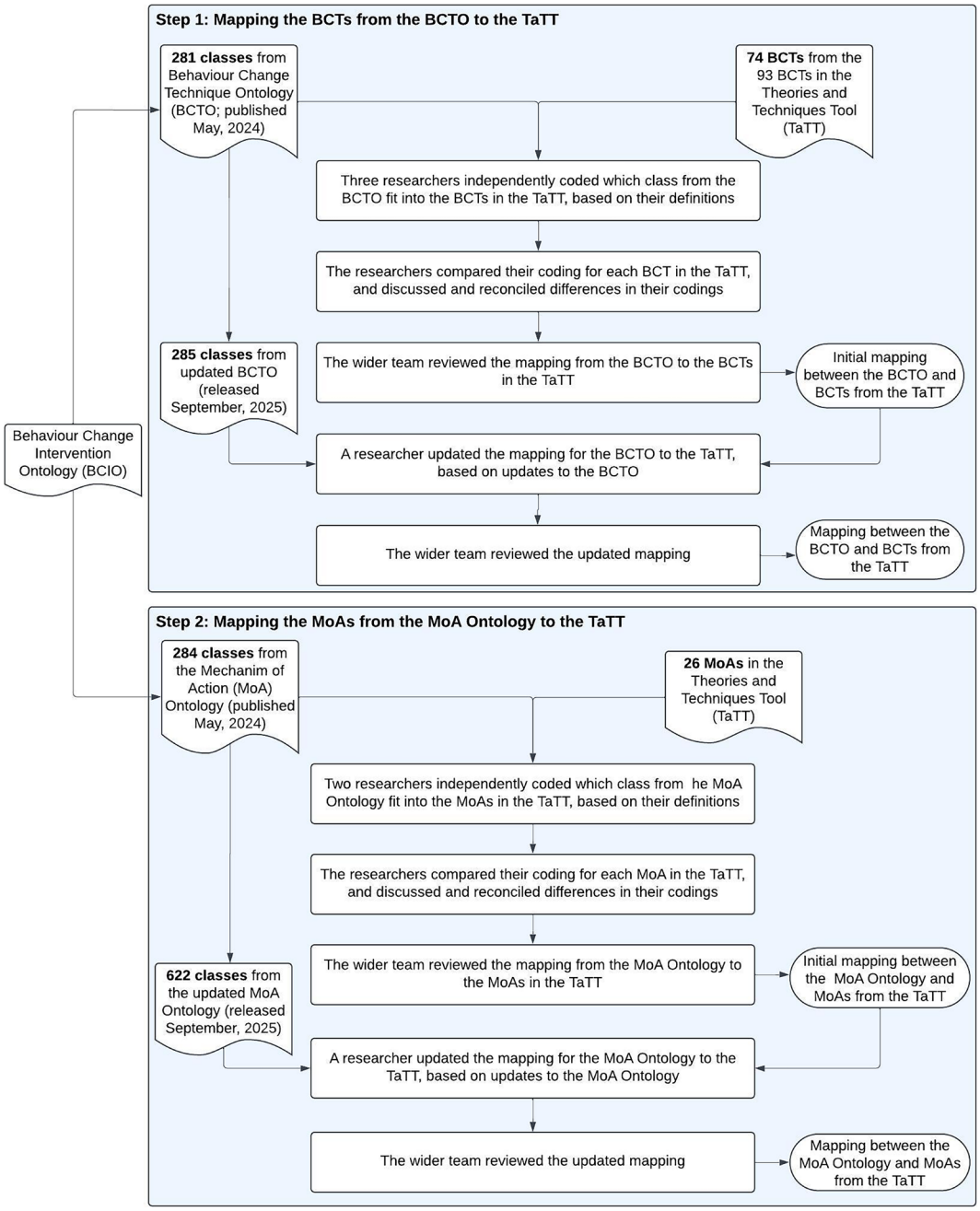

Figure 5. Overview of the steps to map the BCTO and MoA Ontology to the TaTT.

wider research team then reviewed these results and discussed whether additional classes from the ontology or new classes were needed to clearly capture any of the 74 BCTs from the TaTT.

Following this initial mapping, updates were made to the BCTO as part of another study (Michie *et al.*, prep), resulting in four new classes being added. A researcher (LZ) updated the mapping to reflect the changes to the ontology (released September, 2025), recording relevant new classes for BCTs in the TaTT, and then verified the updated mapping with research group. The most recent version of the BCTO can be downloaded from https://github.com/HumanBehaviourChangeProject/ontologies/tree/master/BehaviourChangeTechniques.

Step 2: Mapping the MoAs from the MoA Ontology to the TaTT

Two researchers (PS, MS) independently reviewed the 284 class labels and definitions in the MoA Ontology (published May, 2024; see this version in https://osf.io/pkq4e) and recorded which

classes were captured by each of the 26 MoA groups in the TaTT (https://theoryandtechniquetool.humanbehaviourchange.org/tool). For a class to be considered as captured by an MoA in the TaTT, the class definition needed to: (1) have an identical meaning to the TaTT MoA definition or (2) include all the attributes of the MoA's definition while providing more specific detail.

The researchers did not do the reverse mapping, i.e., mapping TaTT MoAs to specific classes in the MoA Ontology. This approach differed from how we mapped BCTs, where it sometimes made sense to group several TaTT BCTs under broader classes in the BCTO. We avoided this here, because the TaTT MoAs are often very broad and can include subcomponents that belong to different parts of the MoA Ontology's hierarchy. As a result, many TaTT MoAs would only map onto high-level structural classes (e.g., "mental disposition"), which are too broad to be practically meaningful. For example, the TaTT MoA "Social/Professional role & identity" includes the MoAs "personal role" [BCIO:006081] and "identity" [ADDICTO:0000381]. Since these are not closely related in the ontology's logical hierarchy, the only possible mapping would be to a very general class such as "characteristic" [BFO:0000020] in the BCIO. Therefore, to be more useable, the mapping between these tools was kept simpler.

After their independent coding, the researchers compared their coding, discussing and reconciling their disagreements to finalise their mapping. The wider research team then reviewed these results and discussed whether additional classes from the ontology or new classes were needed to clearly capture any groups.

The MoA mapping needed to be revised to reflect substantial changes to the MoA Ontology (released September, 2025 since its initial publication). A researcher (PS) reviewed the 338 new classes added to the ontology (with 622 classes in total) and recorded the relevant ones for MoA groups from the TaTT. The new additions were reviewed by the wider research group and added to the mapping based on their feedback. The most recent version of the MoA Ontology can be downloaded from https://github.com/HumanBehaviourChangeProject/ontologies/tree/master/MechanismOfAction.

Results

Step 1: Mapping the BCTs from the BCTO to the TaTT

From the BCTO, 85 BCTs (classes) were, altogether, mapped onto the 74 BCTs from the TaTT. Of the BCTs in the BCTO, 59 had a one-to-one mapping to the BCTs listed in the TaTT. For example, the class "Goal strategising BCT [BCIO:007008]" corresponded to the "1.2 Problem solving" in the TaTT. As the BCTO contains more detailed BCTs compared to both BCTTv1 and the TaTT, multiple BCTO classes were mapped to 11 BCTs in the TaTT: nine TaTT BCTs each corresponded to two BCTO classes, while two TaTT BCTs corresponded to three BCTO classes. For example, the classes "Prompt intended action BCT [BCIO:007080]" and "Cue BCT [BCIO:007081]" were both mapped to "7.1 Prompts/cues" in the TaTT. Another key change in the BCTO from the BCTTv1 was no longer distinguishing between self- and other-enacted BCTs, as the source of an intervention is now specified through the Source Ontology (Norris *et al.*, 2021). This meant that the ontological class "Provide positive consequence for behaviour BCT" [BCIO:007252 (URI, i.e. alphanumeric ID)] was mapped onto the TaTT BCTs "10.3 Non-specific reward" and "10.9 Self-reward". Similarly, the class "Promise positive consequence for behaviour BCT" [BCIO:007202] was mapped onto "10.6 Non-specific incentive" and "10.7 Self-incentive". Table 2 presents the mapping. The BCTs from the TaTT that have one-on-one mappings with BCTO classes are also cross-referenced within the ontology. For reference, the earlier mapping of the BCTO (released May, 2024) can be found here: https://osf.io/r7cux)

Table 2. Mapping the 74 BCTs in the TaTT to the BCTs in the BCTO (Johnston *et al.*, 2018; Johnston *et al.*, 2021; Marques *et al.*, 2024b; Michie *et al.*, 2013).

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
1	**1.1 Goal setting (behaviour):** Set or agree on a goal defined in terms of the behaviour to be achieved	**Set behaviour goal BCT [BCIO:007003]*:** A <goal setting BCT> that sets a goal for the behaviour to be achieved. • **Set measurable behaviour goal BCT [BCIO:007300]:** A <set behaviour goal BCT> that describes the behaviour to be achieved in terms of a measurable target. **Agree behaviour goal BCT [BCIO:007004]**: A <goal setting BCT> that involves the intervention source agreeing with the person on a behavioural goal.
2	**1.2 Problem solving:** Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators	**Goal strategising BCT [BCIO:007008]:** A <goal directed BCT> in which the person analyses factors influencing the behaviour and generates, selects, or reviews strategies to increase facilitators and overcome barriers.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
3	**1.3 Goal setting (outcome):** Set or agree on a goal defined in terms of a positive outcome of wanted behaviour	**Set outcome goal BCT [BCIO:007005]*:** A <goal setting BCT> in which the goal is a positive outcome of performing the behaviour. • **Set measurable outcome goal BCT [BCIO:007301]:** A <set outcome goal BCT> that describes the behavioural outcome to be achieved in terms of a measurable target. **Agree outcome goal BCT [BCIO:007006]**: A <goal setting BCT> that involves the intervention source agreeing with the person on a goal which is a positive outcome of performing the behaviour.
4	**1.4 Action planning:** Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive)	**Action planning BCT [BCIO:007010]:** A <goal directed BCT> that involves making a detailed plan for the performance of the behaviour, which must include at least one of context, frequency, duration or intensity.
5	**1.5 Review behaviour goal(s):** Review behaviour goal(s) jointly with the person and consider modifying goal(s) or behaviour change strategy in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of (or in addition to) the first, or no change.	**Review behaviour goal BCT [BCIO:007011]**: A <goal directed BCT> that reviews a behavioural goal and considers modifying the goal in light of progress toward the goal.
6	**1.6 Discrepancy between current behaviour and goal**: Draw attention to discrepancies between a person's current behaviour (in terms of the form, frequency, duration, or intensity of that behaviour) and the person's previously set outcome goals, behavioural goals or action plans (goes beyond self-monitoring of behaviour)	**Attend to discrepancy between current behaviour and goal BCT [BCIO:007012]:** A <goal directed BCT> that draws attention to discrepancies between a person's current behaviour and the person's outcome goal, behavioural goal or action plan.
7	**1.7 Review outcome goal(s):** Review outcome goal(s) jointly with the person and consider modifying goal(s) in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of, or in addition to the first	**Review outcome goal BCT [BCIO:007013]**: A <goal directed BCT> that reviews an outcome goal and considers modifying the goal in light of achievement.
8	**1.8 Behavioural contract**: Create a written specification of the behaviour to be performed, agreed on by the person, and witnessed by another	**Create behavioural contract BCT [BCIO:007014]**: A <goal directed BCT> that creates a written specification of the behaviour to be performed, agreed on by the person, and witnessed by another person.
9	**1.9 Commitment**: Ask the person to affirm or reaffirm statements indicating commitment to change the behaviour	**Affirm commitment BCT [BCIO:007015]:** A <goal directed BCT> that asks the person to affirm or reaffirm statements indicating commitment to change the behaviour.
10	**2.1 Monitoring of behaviour by others without feedback**: Observe or record behaviour with the person's knowledge as part of a behaviour change strategy	**Observe behaviour without feedback BCT [BCIO:007018]:** A <monitoring BCT> that monitors current performance of the behaviour with the person's knowledge but without providing feedback about their behaviour. **Record behaviour without feedback BCT [BCIO:007019]:** A <monitoring BCT> that documents current performance of the behaviour with the person's knowledge but without providing feedback about their behaviour.
11	**2.2 Feedback on behaviour:** Monitor and provide informative or evaluative feedback on performance of the behaviour *(e.g. form, frequency, duration, intensity)*	**Provide feedback on behaviour BCT [BCIO:007023]**: A <provide feedback BCT> that provides information about the person's previous performance of the behaviour.
12	**2.3 Self-monitoring of behaviour:** Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy	**Self-monitor behaviour BCT [BCIO:007024]**: A <monitoring BCT> in which the person uses a method to monitor and record their behaviour.
13	**2.4 Self-monitoring outcome(s) of behaviour:** Establish a method for the person to monitor and record the outcome(s) of their behaviour as part of a behaviour change strategy	**Self-monitor outcome of behaviour BCT [BCIO:007025]**: A <monitoring BCT> in which the person uses a method to monitor and record an outcome of their behaviour.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
14	**2.5 Monitoring of outcome(s) of behaviour by others without feedback:** Observe or record outcomes of behaviour with the person's knowledge as part of a behaviour change strategy	**Observe outcome of behaviour without feedback BCT [BCIO:007020]:** A <monitoring BCT> that monitors an outcome of performing the behaviour with the person's knowledge but without providing feedback about the outcome. **Record outcome of behaviour without feedback BCT [BCIO:007021]:** A <monitoring BCT> that documents an outcome of performing the behaviour with the person's knowledge but without providing feedback about the outcome.
15	**2.6 Biofeedback:** Provide feedback about the body *(e.g. physiological or biochemical state)* using an external monitoring device as part of a behaviour change strategy	**Provide biofeedback BCT [BCIO:007026]:** A <provide feedback BCT> that provides information about the functioning or state of the person's body, based on information collected by an external monitoring device.
16	**2.7 Feedback on outcome(s) of behaviour:** Monitor and provide feedback on the outcome of performance of the behaviour	**Provide feedback on outcome of behaviour BCT [BCIO:007027]:** A <provide feedback BCT> that provides information about an outcome of the person's previous performance of the behaviour.
17	**3.1 Social support (unspecified):** Advise on, arrange or provide social support *(e.g. from friends, relatives, colleagues,' buddies' or staff)* or non-contingent praise or reward for performance of the behaviour. It includes encouragement and counselling, but only when it is directed at the behaviour	**Social support BCT [BCIO:007028]*:** A <behaviour change technique> that involves taking steps to secure or deliver the support or aid of another person. • **Advise to seek support BCT [BCIO:007029]:** A <social support BCT> that involves advising the person to seek support from another person. • **Arrange support BCT [BCIO:007034]:** A <social support BCT> that organises support from another for the person. • **Deliver support BCT [BCIO:007039]:** A <social support BCT> that directly provides support to the person.
18	**3.2 Social support (practical):** Advise on, arrange, or provide practical help *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behaviour	**Advise to seek instrumental support BCT [BCIO:007030]:** An <advise to seek support BCT> that suggests the person try to obtain support from another in terms of tangible aid. **Arrange instrumental support BCT [BCIO:007035]:** An <arrange support BCT> that organises support from another in terms of tangible aid. **Deliver instrumental support BCT [BCIO:007040]:** A <deliver support BCT> that provides tangible aid.
19	**3.3 Social support (emotional):** Advise on, arrange, or provide emotional social support *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behaviour	**Advise to seek emotional support BCT [BCIO:007031]:** An <advise to seek support BCT> that suggests the person try to obtain support from another in terms of expressing concern, caring and empathy. **Arrange emotional support BCT [BCIO:007036]:** An <arrange support BCT> that organises support from another in terms of expressing concern, caring and empathy. **Deliver emotional support BCT [BCIO:007041]:** A <deliver support BCT> that provides expressions of concern, caring and empathy.
20	**4.1 Instruction on how to perform behaviour:** Advise or agree on how to perform the behaviour	**Instruct how to perform behaviour BCT [BCIO:007058]:** A <guide how to perform behaviour BCT> that involves telling the person how to perform the behaviour. **Agree on how to perform behaviour BCT [BCIO:007051]:** A <guide how to perform behaviour BCT> that involves reaching consensus on how to perform the behaviour.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
21	**4.2 Information about antecedents:** Provide information about antecedents *(e.g. social and environmental situations and events, emotions, cognitions)* that reliably predict performance of the behaviour	**Inform about antecedents BCT [BCIO:007052]:** A <suggest different perspective on behaviour BCT> that involves providing factual information to the person regarding triggers or influences that precede the initiation of the behaviour.
22	**4.3 Re-attribution:** Elicit perceived causes of behaviour and suggest alternative explanations *(e.g. external or internal and stable or unstable)*	**Re-attribute cause BCT [BCIO:007053]:** A <suggest different perspective on behaviour BCT> that involves eliciting the person's beliefs about, and suggesting alternative beliefs about, the causes of the behaviour.
23	**5.1 Information about health consequences:** Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour	**Inform about health consequences BCT [BCIO:007063]*:** An <increase awareness of consequences BCT> that provides information about the physical or mental health consequences of performing or not performing the behaviour. • **Inform about positive health consequences BCT [BCIO:007183]:** An <inform about health consequences BCT> that provides information about the positive physical or mental health consequences of performing or not performing the behaviour. • **Inform about negative health consequences BCT [BCIO:007179]**: An <inform about health consequences BCT> that provides information about the negative physical or mental health consequences of performing or not performing the behaviour.
24	**5.2 Salience of consequences:** Use methods specifically designed to emphasise the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences)	**Increase salience of consequences BCT [BCIO:007068]:** An <increase awareness of consequences BCT> that emphasises the consequences in a way that makes them more vivid or emotionally-laden.
25	**5.3 Information about social and environmental consequences:** Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behaviour	**Inform about social consequences BCT [BCIO:007064]*:** An <increase awareness of consequences BCT> that provides information about the social consequences of performing or not performing the behaviour. • **Inform about positive social consequences BCT [BCIO:007184]**: An <inform about social consequences BCT> that provides information about the positive social consequences of performing or not performing the behaviour. • **Inform about negative social consequences BCT [BCIO:007180]:** An <inform about social consequences BCT> that provides information about the negative social consequences of performing or not performing the behaviour. **Inform about environmental consequences BCT [BCIO:007176]*:** An <increase awareness of consequences BCT> that provides information about the environmental consequences of performing or not performing the behaviour. • **Inform about positive environmental consequences BCT [BCIO:007182]:** An <inform about environmental consequences BCT> that provides information about the positive environmental consequences of performing or not performing the behaviour. • **Inform about negative environmental consequences BCT [BCIO:007178]:** An <inform about environmental consequences BCT> that provides information about the negative environmental consequences of performing or not performing the behaviour.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
26	**5.4 Monitoring of emotional consequences**: Prompt assessment of feelings after attempts at performing the behaviour	**Monitor emotional consequences BCT [BCIO:007066]:** A <monitoring BCT> that involves the person assessing their emotions after performing the behaviour
27	**5.5 Anticipated regret:** Induce or raise awareness of expectations of future regret about performance of the unwanted behaviour	**Induce anticipated regret BCT [BCIO:007067]:** An <inform about emotional consequences BCT> that focuses on expectations of remorse after performing or not performing the behaviour.
28	**5.6 Information about emotional consequences:** Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behaviour	**Inform about emotional consequences BCT [BCIO:007065]*:** An <increase awareness of consequences BCT> that provides information about the emotional consequences of performing or not performing the behaviour. • **Inform about positive emotional consequences BCT [BCIO:007181]:** An <inform about emotional consequences BCT> that provides information about the positive emotional consequences of performing or not performing the behaviour. • **Inform about negative emotional consequences BCT [BCIO:007177]:** An <inform about emotional consequences BCT> that provides information about the negative emotional consequences of performing or not performing the behaviour.
29	**6.1 Demonstration of the behaviour:** Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate	**Demonstrate the behaviour BCT [BCIO:007055]:** A <guide how to perform behaviour BCT> that provides an observable sample of the performance of the behaviour for the person to aspire to or imitate.
30	**6.2 Social comparison:** Draw attention to others' performance to allow comparison with the person's own performance	**Prompt social comparison BCT [BCIO:007073]:** An <awareness of other people's thoughts, feelings and actions BCT> that draws attention to other people's behaviour and compares it with the person's own behaviour.
31	**6.3 Information about others' approval:** Provide information about what other people think about the behaviour. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do	**Increase awareness of others' approval BCT [BCIO:007074]:** An <awareness of other people's thoughts, feelings and actions BCT> that increases awareness of whether others will like, approve, dislike, or disapprove of the behaviour.
32	**7.1 Prompts/cues:** Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour. The prompt or cue would normally occur at the time or place of performance	**Prompt intended action BCT [BCIO:007080]:** An <alter external stimulus BCT> that involves introducing an external stimulus to facilitate the behaviour for which an intention has previously been formed. **Cue BCT [BCIO:007081]:** An <alter external stimulus BCT> that introduces external information that is already associated with the behaviour in order to elicit that behaviour.
33	**7.5 Remove aversive stimulus:** Advise or arrange for the removal of an aversive stimulus to facilitate behaviour change	**Remove aversive stimulus BCT [BCIO:050331]:** An <alter external stimulus BCT> that involves removing an aversive stimulus to bring about behaviour change.
34	**7.7 Exposure:** Provide systematic confrontation with a feared stimulus to reduce the response to a later encounter	**Expose to sustained aversive stimulus BCT [BCIO:007170]:** An <expose to stimulus BCT> that involves sustained exposure to an aversive stimulus to reduce the likelihood of the behaviour when encountering that stimulus. **Gradually increase exposure to aversive stimulus BCT [BCIO:007172]**: An <expose to stimulus BCT> that involves gradually increasing exposure to an aversive stimulus to reduce the likelihood of the behaviour when encountering that stimulus.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
35	**7.8 Associative learning:** Present a neutral stimulus jointly with a stimulus that already elicits the behaviour repeatedly until the neutral stimulus elicits that behaviour	**Associative learning BCT [BCIO:007090]**:** A <behaviour change technique> that involves repeated pairing of a stimulus with another stimulus or with a behavioural outcome.
36	**8.1 Behavioural practice/rehearsal:** Prompt practice or rehearsal of the performance of the behaviour one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill	**Practise behaviour BCT [BCIO:007094]:** An <advise specific behaviour BCT> that advises repetition of the behaviour in a way that has the function of increasing the skill in performing the behaviour.
37	**8.2 Behaviour substitution:** Prompt substitution of the unwanted behaviour with a wanted or neutral behaviour	**Substitute behaviour BCT [BCIO:007095]:** An <advise specific behaviour BCT> that advises the person to replace the unwanted behaviour with another behaviour.
38	**8.3 Habit formation:** Prompt rehearsal and repetition of the behaviour in the same context repeatedly so that the context elicits the behaviour	**Context-specific repetition of behaviour BCT [BCIO:007096]:** An <advise specific behaviour BCT> that advises the person to repeat the behaviour in the same context.
39	**8.4 Habit reversal:** Prompt rehearsal and repetition of an alternative behaviour to replace an unwanted habitual behaviour	**Context-specific repetition of alternative behaviour BCT [BCIO:007097]:** An <advise specific behaviour BCT> that advises the person to repeat an alternative behaviour consistently in a context that previously elicited an unwanted behaviour.
40	**8.6 Generalisation of target behaviour:** Advise to perform the wanted behaviour, which is already performed in a particular situation, in another situation	**Generalise behaviour BCT [BCIO:007099]:** An <advise specific behaviour BCT> that advises the person to perform the behaviour which is already performed in a particular context, in a similar context.
41	**8.7 Graded tasks:** Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behaviour is performed	**Set graded tasks BCT [BCIO:007100]:** A <goal directed BCT> that sets easy-to-perform tasks for the person, making them increasingly difficult, but achievable, until the behaviour is performed.
42	**9.1 Credible source:** Present verbal or visual communication from a credible source in favour of or against the behaviour	**Present information from credible influence BCT [BCIO:007075]:** An <awareness of other people's thoughts, feelings and actions BCT> that presents information from a credible person or organisation to influence the behaviour.
43	**9.2 Pros and cons:** Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behaviour (includes '**Decisional balance'**)	**Consider pros and cons BCT [BCIO:007069]:** An <increase awareness of consequences BCT> that advises identification and comparison of the positive and negative consequences of performing or not performing the behaviour.
44	**9.3 Comparative imagining of future outcomes:** Prompt or advise the imagining and comparing of future outcomes of changed versus unchanged behaviour	**Prompt comparative imagining of future outcomes BCT [BCIO:007070]:** An <increase awareness of consequences BCT> that guides the person to imagine and compare the consequences of performing and not performing the behaviour.
45	**10.1 Material incentive (behaviour):** Inform that money, vouchers or other valued objects *will be* delivered if and only if there has been effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**)	**Promise positive material consequence for behaviour BCT [BCIO:007209]:** A <promise positive consequence for behaviour BCT> where the consequence is money, vouchers or other valued objects.
46	**10.2 Material reward (behaviour):** Arrange for the delivery of money, vouchers or other valued objects if and only if there *has been* effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**)	**Provide positive material consequence for behaviour BCT [BCIO:007257]:** A <provide positive consequence for behaviour BCT> where the consequence is money, vouchers or other valued objects.
47	**10.3 Non-specific reward:** Arrange delivery of a reward if and only if there *has been* effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**)	**Provide positive consequence for behaviour BCT [BCIO:007252]**:** A <provide consequence for behaviour BCT> where the consequence is positive.
48	**10.4 Social reward:** Arrange verbal or non-verbal reward if and only if there *has been* effort and/or progress in performing the behaviour (includes '**Positive reinforcement**')	**Provide positive social consequence for behaviour BCT [BCIO:007265]:** A <provide positive consequence for behaviour BCT> where the consequence is an interpersonal process or a proxy interpersonal process.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
49	**10.6 Non-specific incentive:** Inform that a reward *will be* delivered if and only if there has been effort and/or progress in performing the behaviour (includes '**Positive reinforcement'**)	**Promise positive consequence for behaviour BCT [BCIO:007202]**:** A <promise consequence for behaviour BCT> where the consequence is positive.
50	**10.7 Self-incentive:** Plan to reward self in future if and only if there has been effort and/or progress in performing the behaviour	The BCTO no longer distinguishes between self- and other-enacted BCTs so this BCT is mapped to: **Promise positive consequence for behaviour BCT [BCIO:007202]**:** A <promise consequence for behaviour BCT> where the consequence is positive.
51	**10.8 Incentive (outcome):** Inform that a reward *will be* delivered if and only if there has been effort and/or progress in achieving the behavioural outcome (*includes* **'Positive reinforcement'**)	**Promise positive consequence for outcome of behaviour BCT [BCIO:007216]***: A <promise consequence for outcome of behaviour BCT> where the consequence is positive • **Promise positive social consequence for outcome of behaviour BCT [BCIO:007224]:** A <promise positive consequence for outcome of behaviour BCT> in which the consequence is an interpersonal process or a proxy interpersonal process. • **Promise positive material consequence for outcome of behaviour BCT [BCIO:007215]:** A <promise positive consequence for outcome of behaviour BCT> in which the consequence is money, vouchers or other valued objects.
52	**10.9 Self-reward:** Prompt self-praise or self-reward if and only if there *has been* effort and/or progress in performing the behaviour	The BCTO no longer distinguishes between self- and other-enacted BCTs so this BCT is mapped to: **Provide positive consequence for behaviour BCT [BCIO:007252]**:** A <provide consequence for behaviour BCT> where the consequence is positive.
53	**10.10 Reward (outcome):** Arrange for the delivery of a reward if and only if there *has been* effort and/or progress in achieving the behavioural outcome (includes '**Positive reinforcement**')	**Provide positive consequence for outcome of behaviour BCT [BCIO:007264]****: A <provide consequence for outcome of behaviour BCT> where the consequence is positive.
54	**11.1 Pharmacological support:** Provide, or encourage the use of or adherence to, drugs to facilitate behaviour change	**Promote pharmacological support BCT [BCIO:007144]*:** A <behaviour change technique> promoting medicines or other drugs. • **Provide pharmacological support BCT [BCIO:007145]:** A <promote pharmacological support BCT> that provides the person with medicines or other drugs. • **Encourage pharmacological support BCT [BCIO:007146]:** A <promote pharmacological support BCT> that encourages the person to use medicines or other drugs.
55	**11.2 Reduce negative emotions:** Advise on ways of reducing negative emotions to facilitate performance of the behaviour (includes '**Stress Management**')	**Advise how to reduce negative emotions BCT [BCIO:050344]:** An <advise how to change emotions BCT> suggesting a method to decrease negative emotions.
56	**11.3 Conserving mental resources:** Advise on ways of minimising demands on mental resources to facilitate behaviour change	**Conserve mental resources BCT [BCIO:007134]:** A <manage mental processes BCT> that advises a way to minimise demands on mental resources.
57	**11.4 Paradoxical instructions:** Advise to engage in some form of the unwanted behaviour with the aim of reducing motivation to engage in that behaviour	**Advise paradoxical behaviour BCT [BCIO:007135]:** An <advise specific behaviour BCT> that advises the person to engage in an unwanted behaviour in a way that is aversive.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
58	**12.1 Restructuring the physical environment:** Change, or advise to change the physical environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments)	**Restructure the physical environment BCT [BCIO:050348]**:** A <restructure the environment BCT> that alters the physical environment in which the behaviour is, or would have been, performed in a way that facilitates or impedes the behaviour.
59	**12.2 Restructuring the social environment:** Change, or advise to change the social environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments)	**Restructure the social environment BCT [BCIO:050349]*:** A <restructure the environment BCT> that alters the social environment in which the behaviour is, or would have been, performed in a way that facilitates or impedes the behaviour. • **Directly restructure the social environment BCT [BCIO:050346]**: A <restructure the social environment BCT> that changes the person's directly experienced environment at the time the behaviour is, or would have been, performed. • **Indirectly restructure the social environment BCT [BCIO:050347]:** A <restructure the social environment BCT> that changes the person's environment at a time or location other than when and where the behaviour is performed.
60	**12.3 Avoidance/reducing exposure to cues for the behaviour:** Advise on how to avoid exposure to specific social and contextual/physical cues for the behaviour, including changing daily or weekly routines	**Reduce exposure to cues for the behaviour BCT [BCIO:007153]:** An <alter external stimulus BCT> that reduces an external stimulus that signals the behaviour.
61	**12.5 Adding objects to the environment:** Add objects to the environment in order to facilitate performance of the behaviour	**Add objects to the environment BCT [BCIO:007156]*:** An <environmental restructuring BCT> that adds objects to the person's physical surroundings. • **Add objects to the directly experienced environment BCT [BCIO:007163]:** An <add objects to the environment BCT> that adds an object to the person's directly experienced environment at the time the behaviour is, or would have been, performed. • **Add objects to the indirectly experienced environment BCT [BCIO:007164]:** An <add objects to the environment BCT> that adds an object to the person's environment at a time or location other than when and where the behaviour is performed.
62	**12.6 Body changes:** Alter body structure, functioning or support directly to facilitate behaviour change	**Change the body BCT [BCIO:007136]:** A <behaviour change technique> that alters the structure or functioning of the person's body.
63	**13.1 Identification of self as role model:** Inform that one's own behaviour may be an example to others	**Identify self as role model BCT [BCIO:007158]:** A <prompt focus on self-identity BCT> that informs the person that their behaviour may be an example to others.
64	**13.2 Framing/reframing:** Suggest the deliberate adoption of a perspective or new perspective on behaviour (e.g. its purpose) in order to change cognitions or emotions about performing the behaviour (includes '**Cognitive structuring**')	**Reframe past behaviour BCT [BCIO:007056]:** A <suggest different perspective on behaviour BCT> that involves reattributing a person's successes to internal, stable or global factors or failures to external, unstable or specific factors.
65	**13.3 Incompatible beliefs:** Draw attention to discrepancies between current or past behaviour and self-image, in order to create discomfort (includes '**Cognitive dissonance'**)	**Draw attention to incompatible beliefs BCT [BCIO:007057]:** A <suggest different perspective on behaviour BCT> that draws the person's attention to the discrepancies between current or past behaviour and self-identity.
66	**13.4 Valued self-identity:** Advise the person to write or complete rating scales about a cherished value or personal strength as a means of affirming the person's identity as part of a behaviour change strategy (includes '**Self-affirmation'**)	**Affirm valued self-identity BCT [BCIO:007159]:** A <prompt focus on self-identity BCT> that advises engagement in activities that affirm the person's valued attributes.

No.	BCT in the TaTT	Corresponding BCT classes in the BCT Ontology
67	**13.5 Identity associated with changed behaviour:** Advise the person to construct a new self-identity as someone who 'used to engage with the unwanted behaviour'	**Adopt changed self-identity BCT [BCIO:007160]:** A <prompt focus on self-identity BCT> that promotes the adoption of a self-identity as someone who engages in the behaviour that is different from their previous behaviour.
68	**14.2 Punishment:** Arrange for aversive consequence contingent on the performance of the unwanted behaviour	**Provide aversive consequence for behaviour BCT [BCIO:007241]**:** A <provide consequence for behaviour BCT> where the consequence is aversive.
69	**15.1 Verbal persuasion about capability:** Tell the person that they can successfully perform the wanted behaviour, arguing against self-doubts and asserting that they can and will succeed	**Persuade about personal capability BCT [BCIO:007137]:** A <prompt thinking related to successful performance BCT> that persuades the person that they can successfully perform the behaviour.
70	**15.2 Mental rehearsal of successful performance:** Advise to practise imagining performing the behaviour successfully in relevant contexts	**Prompt mental rehearsal of successful performance BCT [BCIO:007138]:** A <prompt thinking related to successful performance BCT> that prompts the person to practise imagining performing the behaviour well in a relevant context.
71	**15.3 Focus on past success:** Advise to think about or list previous successes in performing the behaviour (or parts of it)	**Prompt focus on past success BCT [BCIO:007139]:** A <prompt thinking related to successful performance BCT> that prompts the person to think about previous successful performance of the behaviour.
72	**15.4 Self-talk:** Prompt positive self-talk (aloud or silently) before and during the behaviour	**Prompt self-talk BCT [BCIO:007140]:** A <prompt thinking related to successful performance BCT> that promotes the use of positive self-talk before or during the behaviour.
73	**16.2 Imaginary reward:** Advise to imagine performing the **wanted** behaviour in a real-life situation followed by imagining a pleasant consequence (includes **'Covert conditioning'**)	**Imagine reward BCT [BCIO:007119]:** An <increase awareness of consequences BCT> that guides the person to imagine performing the wanted behaviour in a real-life situation followed by experiencing a pleasant consequence for performing that behaviour.
74	**16.3 Vicarious consequences:** Prompt observation of the consequences (including rewards and punishments) for others when they perform the behaviour	**Vicarious reward BCT [BCIO:007120]:** An <increase awareness of consequences BCT> that prompts observation of another person being rewarded when they perform the behaviour. **Vicarious punishment BCT [BCIO:007121]:** An <increase awareness of consequences BCT> that prompts observation of another person being punished when they perform the behaviour.

Note. BCT = Behaviour Change Technique; BCTO = Behaviour Change Technique Ontology; TaTT = Theory and Technique Tool

* In these cases, both a class and its subclasses are shown in the mapping. This was done as the subclasses were considered to capture important aspects of a BCT group and would be useful to view in the mapping.

** This BCT has a large number of child classes – please refer to the full BCTO (https://github.com/HumanBehaviourChangeProject/ontologies/blob/master/BehaviourChangeTechniques/BCIO-bcto-hierarchy.xlsx) for details

Step 2: Mapping the MoAs from the MoA Ontology to the TaTT

Drawing on the MoA Ontology's most recent version (released February, 2025), 56 classes (not counting their subclasses) were, altogether, mapped onto the 26 MoAs (1–5 classes per MoA in the TaTT). Eight ontology classes had a one-to-one mapping to TaTT MoAs, such as the class "Knowledge" (BCIO:00605) class corresponding to the TaTT MoA "Knowledge". Since the ontology included more specific classes than the MoAs in the TaTT, each of the remaining 18 MoAs in the TaTT corresponded to two to five classes. For example, the following ontology classes were mapped onto the broader TaTT MoA "Memory, attention & decision processes": "Memory process" [BCIO:050319], "Attending" [MF:0000018], "Attentional disposition" [BCIO:050572] and "Decision-making" [BCIO:006116]. The complete mapping can be seen in Table 3. The TaTT MoAs that have one-on-one mappings with classes in the MoA Ontology were explicitly included as examples in the ontology.

Not all relevant subclasses are presented in this table, unless they capture important aspects of a TaTT MoA. Therefore,

further engaging with the mapped ontology classes (e.g., viewing their subclasses) can help identify more detailed MoAs that are investigated or explored in studies. For example, the subclasses of "Memory process" [BCIO:050319] include: "Associative memory" [BCIO:006126], "Episodic memory" [BCIO:006127], "Iconic memory" [BCIO:006130], "Procedural memory" [BCIO:006129] and "Semantic memory" [BCIO:006128].

For reference, the earlier mapping of the MoA Ontology (released May, 2024) to the TaTT can be found here: https://osf.io/zmub5 and the initial mapping by the researchers here: https://osf.io/ycdzv). During the coding process, some disagreements arose over how strictly ontology classes should be mapped to the 26 MoAs, given that the MoA Ontology contains more detailed and specific classes. These disagreements were resolved through discussions, and minor changes were made to the MoA Ontology where needed. Three classes were added to the MoA Ontology, with one class (e.g., "Affective attitude towards a behaviour" [BCIO:050327]) being added to more fully capture the MoA group "Attitude towards a behaviour" and two ("Attitude" [BCIO:050328] and "Affective attitude" [BCIO:050326]) to better capture "General Beliefs/Attitude".

Table 3. Mapping the 26 MoAs in the TaTT to the MoAs in the MoA Ontology (Johnston *et al.*, 2018; Johnston *et al.*, 2021; Schenk *et al.*, 2024).

No.	MoA in the TaTT	Corresponding MoA classes in the MoA Ontology
1	**Knowledge**: An awareness of the existence of something	**Knowledge [BCIO:00605]**: A <mental disposition> to understand the nature of the world, or a specific aspect of the world, that corresponds to the actual state of the world and is acquired through experience or learning.
2	**Skill**: An ability or proficiency acquired through practice.	**Mental skill [BCIO:006004]**: A <mental capability> acquired through training or practice. **Self-regulatory skill [BCIO:050222]**: A <self-regulation capability> that is acquired through training or practice. **Physical skill [BCIO:006010]**: A <physical behavioural capability> acquired through training or practice. **Social skill [BCIO:006012]**: A <social behavioural capability> acquired through training or practice.
3	**Social/Professional role & identity**: A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting	**Personal role [BCIO:006081]*:** A <role> that inheres in a human being by virtue of their social and institutional circumstances. • **Occupational role [BCIO:015430]:** A <personal role> that is realised in a person by doing a specified type of work or working in a specified way. • **Social role [BCIO:006082]:** A <personal role> that is realised in human social processes. **Identity [ADDICTO:0000381]*:** A <cognitive representation> of themselves by a person or group. • **Self-identity [ADDICTO:0000399]:** An <identity> that a person has about themselves. ○ **Professional identity [BCIO:050229]:** A <self-identity> that is associated with one's occupational role. ○ **Social identity [ADDICTO:0001087]:** A <self-identity> that represents a relation between oneself and another person or group • **Group identity [ADDICTO:0000715]:** An <identity> that a group holds about itself.
4	**Beliefs about capabilities:** Beliefs about one's ability to successfully carry out a behaviour.	**Self-efficacy belief for a behaviour and its associated outcomes [BCIO:006043]:** A <self-efficacy belief> to organise and execute a behaviour and achieve the outcomes associated with this behaviour. **Self-efficacy belief for a behaviour [BCIO:006154]**: A <self-efficacy belief> to organise and execute a behaviour.

No.	MoA in the TaTT	Corresponding MoA classes in the MoA Ontology
5	**Optimism:** Confidence that things will happen for the best or that desired goals will be attained.**	**Belief about likelihood of consequences of an occurrence [BCIO:006026]:** A <belief> in terms the probability that a given event or state will occur or not occur in the future. **Evaluative belief [BCIO:006038]:** A <belief> about whether a particular aspect of the world is positive or negative.
6	**Beliefs about consequences:** Beliefs about the consequences of a behaviour (i.e. perceptions about what will be achieved and/or lost by undertaking a behaviour, as well as the probability that a behaviour will lead to a specific outcome).	**Belief about consequences of behaviour [BCIO:006019]:** A < belief about consequences of an occurrence > in terms of what results from or follows the performance of a behaviour. Consequences can be either positive or negative. **Belief about likelihood of consequences of behaviour [BCIO:006024]:** A <belief about likelihood of consequences of an occurrence> in terms of the probability that a behaviour will result or not result in particular outcomes.
7	**Reinforcement:** Processes by which the frequency or probability of a response is increased through a dependent relationship or contingency with a stimulus or circumstance.	**Internal reward for a response [BCIO:006100]:** A <bodily process> by which the person experiences an internally-generated positive physical or psychological state subsequent to a response. **Reinforcement process [BCIO:050755]:** A <process> in which a behaviour is followed by an event that alters the likelihood of occurrence of the behaviour.
8	**Intention:** A conscious decision to perform a behaviour or a resolve to act in a certain way.	**Behavioural intention [BCIO:006016]:** A <mental disposition> to commit to enact or not enact a behaviour.
9	**Goals:** Mental representations of outcomes or end states that an individual wants to achieve.	**Goal [BCIO:006049]:** A <cognitive representation> of an end state towards which one is striving.
10	**Memory, attention & decision processes:** Ability to retain information, focus on aspects of the environment and choose between two or more alternatives.	**Memory process [BCIO:050319]:** A <mental process> that is the encoding, storing, and retrieval of informational stimuli. **Attending [MF:0000018]:** A <mental process> whereby relevant aspects of one's mental experience are focused on specific targets. **Attentional disposition [BCIO:050572]:** A <mental disposition> that is realised by focusing one's attention on events, objects, sensory patterns or cognitive representations. **Decision-making [BCIO:006116]:** <Judging> in which one or more propositions or behaviours are identified as preferred from a larger number.
11	**Environmental context & resources:** Aspects of a person's situation or environment that discourage or encourage the behaviour.	**Environmental system [ENVO:01000254]:** A <system> which has the disposition to surround and interact with one or more material entities. **Environmental disposition [ENVO:01000452]*:** A disposition which is realised by an environmental system or system parts thereof. • **Behavioural opportunity [BCIO:006086]:** An <environmental disposition> that is required for or facilitates a behaviour.
12	**Social influences:** Those interpersonal processes that can cause oneself to change one's thoughts, feelings or behaviours	**Socially-related behaviour [BCIO:050441]*:** An <individual human behaviour> that relates to the social environment. • **Inter-personal behaviour [BCIO:036025]:** A < socially-related behaviour> that involves an interaction between two or more people. ○ **Social influence behaviour [BCIO:006099]:** An <inter-personal behaviour> where a person exerts an influence on the behaviour of another. **Interpersonal process [MF:0000021]*:** A <bodily process> in which at least two human beings are agents. • **Social influence process [BCIO:050776]:** An <interpersonal process> in which people's thoughts, feelings or behaviours are influenced by other people.

No.	MoA in the TaTT	Corresponding MoA classes in the MoA Ontology
13	**Emotion:** A complex reaction pattern involving experiential, behavioural, and physiological elements.	**Emotion process [MFOEM:000001]:** An <affective process> that is a synchronized aggregate of constituent mental processes, including an appraisal process, which is valanced, has an object, and gives rise to an action tendency.
14	**Behavioural regulation:** Behavioural, cognitive and/or emotional skills for managing or changing behaviour.	**Self-regulation capability [BCIO:006005]:** A <mental capability> that involves processes that modulate the frequency, rate or extent of a response to external or internal stimuli and that are instigated by the person themselves. **Self-regulation of behaviour [BCIO:006103]:** A <self-regulation process> that modulates the frequency, rate or extent of one's performance of a behaviour.
15	**Norms:** The attitudes held and behaviours exhibited by other people within a social group.	**Social representation of a behaviour [BCIO:050779]:** A <cognitive representation> about a behaviour that is shared by members of a social group. **Group belief [BCIO:050669]:** A <social group attribute> in which a majority of members of a group have the belief. **Normative behaviour [BCIO:006095]:** An <individual human behaviour> that is commonly enacted by people that are part of a social environmental system. **Group descriptive behavioural norm [BCIO:050670]:** A <social group attribute> a behaviour is common within a social group. **Group evaluative behavioural norm [BCIO:050671]: A** <social group attribute> in which members of the group share an evaluative belief of a behaviour.
16	**Subjective norms:** One's perceptions of what most other people within a social group believe and do.	**Perceived norm [BCIO:006039]*:** A <belief about one's social environment> in terms of what is typical for people who belong to a particular group. • **Perceived descriptive behavioural norm [BCIO:006040]**: A <perceived norm> regarding the prevalence of performance of a given behaviour by people within a group. • **Perceived evaluative behavioural norm [BCIO:006041]:** A <perceived norm> regarding whether a behaviour is appropriate and correct for people who belong to a particular group. • **Normative belief [BCIO:006042]:** A <perceived norm> regarding whether key others think one should perform a behaviour.
17	**Attitude towards the behaviour:** The general evaluations of the behaviour on a scale ranging from negative to positive.	**Evaluative belief about behaviour [BCIO:006147]:** An <evaluative belief> about whether a behaviour is positive or negative. **Affective attitude towards a behaviour [BCIO:050327]:** An <affective attitude> in which the entity that is the attitude object is a behaviour. **Attitude towards a behaviour [BCIO:050329]:** An <attitude> in which the entity that is the attitude object is a behaviour.
18	**Motivation:** Processes relating to the impetus that gives purpose or direction to behaviour and operates at a conscious or unconscious level.	**Behavioural motivation [BCIO:006133]*:** A <mental process> that energises and directs a behaviour. • **Automatic behavioural motivation [BCIO:006134]:** <Behavioural motivation> that arises from emotions and impulses that result from associative learning or innate dispositions. • **Reflective behavioural motivation [BCIO:050318]:** <Behavioural motivation> that involves reflective thinking.
19	**Self-image:** One's conception and evaluation of oneself, including psychological and physical characteristics, qualities and skills.	**Evaluation of self [BCIO:006035]:** An <evaluative belief> about one's attributes. **Self-identity [ADDICTO:0000399]:** An <identity> that a person has about themselves.

No.	MoA in the TaTT	Corresponding MoA classes in the MoA Ontology
20	**Needs:** Deficit of something required for survival, well-being or personal fulfilment.	**Psychological need [BCIO:006064]:** A <mental disposition> of a person to act to obtain or maintain a particular state due to this state's importance to the person's wellbeing. **Subjective need [BCIO:050316]:** A <subjective affective feeling> that is an attraction to an imagined scenario involving anticipated relief from or avoidance of mental or physical discomfort. **Physiological need [BCIO:050734]: A** <bodily disposition> resulting from a discrepancy between a current and target physiological state.
21	**Values:** Moral, social or aesthetic principles accepted by an individual or society as a guide to what is good, desirable or important.	**Personal value [BCIO:006063]:** A <mental disposition> to regard certain things as fundamentally important in life, which informs standards for behaviour.
22	**Feedback processes:** Processes through which current behaviour is compared against a particular standard.	**Social comparison process [BCIO:006118]: <**Judging> oneself or one's social group in relation to the qualities or characteristics of another person or social group. **Mentally comparing against a standard [BCIO:006132]:** A <mental process> in which conditions are compared against a particular reference level. **Feedback process to a person [BCIO:050663]:** A <process> in which information about a bodily process is received by the person.
23	**Social learning/imitation:** A process by which thoughts, feelings and motivational states observed in others are internalised and replicated without the need for conscious awareness.	**Observational learning [GO:0098597]*:** <Learning> that occurs through observing the behaviour of others. • **Imitative learning [GO:0098596]:** <Observational learning> in which new behaviours are acquired through imitation. • **Vicarious learning [BCIO:050794]:** <Observational learning> through the feelings or actions of another person.
24	**Behavioural cueing:** Processes by which behaviour is triggered from either the external environment, the performance of another behaviour, or from ideas appearing in consciousness.	**Behavioural cue [BCIO:050578]:** A <stimulus> that prompts a behaviour or a behaviour pattern. **Reinforcer [BCIO:050756]:** A <stimulus> that changes the likelihood of a preceding behaviour.
25	**General attitudes/beliefs:** Evaluations of an object, person, group, issue or concept on a scale ranging from negative to positive.	**Evaluative belief [BCIO:006038]:** A <belief> about whether a particular aspect of the world is positive or negative. **Affective attitude [BCIO:050326]:** A <mental disposition> to experience a subjective affective feeling about something. **Attitude [BCIO:050328]:** A <mental disposition> that is an affective attitude or an evaluative belief about something.
26	**Perceived susceptibility/vulnerability:** Perceptions of the likelihood that one is vulnerable to a threat.	**Belief about threat [BCIO:006306]:** A <belief> about a potential harm. **Belief about severity of an outcome [BCIO:006030]:** A <belief> about how serious the harm associated with an outcome could be. **Belief about susceptibility to a threat [BCIO:006305]:** A <belief> about vulnerability to a threat.

Note. MoA = Mechanism of Action; MAO = Mechanisms of Action Ontology; TaTT = Theory and Technique Tool

* In some cases, both a class and its subclasses are shown in the mapping. This was done, as the relevant subclasses were considered to capture important aspects of an MoA group and would, therefore, be useful to view in the mapping.

** To capture "Optimism" a combination of "Belief about likelihood of consequences of an occurrence" [BCIO:006026] and "Evaluative belief" [BCIO:006038] are needed, as optimism involves beliefs about likelihoods and an evaluative component. It should be noted that "Optimism" can involve beliefs that negative events are unlikely.

Discussion

The purpose of this study was to align the TaTT and BCIO so that they can be used in combination. This was achieved by mapping the classes from the BCTO onto their corresponding BCTs in TaTT, and the classes from the MoA Ontology to their corresponding MoAs in TaTT. This mapping serves as a resource to develop interventions and more precisely report their BCT-MoA links, thereby helping build a stronger evidence base on the hypothesised pathways through which interventions change behaviour and identify gaps in research.

The current mapping, similar to the TaTT more generally, needs to be applied flexibly and considering evidence about target behaviours and their contexts (Connell *et al.*, 2019). BCT and MoA links greatly vary for interventions with different forms of delivery, schedules, levels of engagement, as well as for different target behaviours, populations and their settings (Davidson & Scholz, 2020; Michie *et al.*, 2020; Perski *et al.*, 2017). Therefore, intervention developers need to take this variation into account, when identifying MoAs and selecting appropriate BCTs using the TaTT and the associated mapping to ontologies. Details about aspects of interventions can be reported using other BCIO lower-level ontologies for: intervention mode of delivery (Marques *et al.*, 2021), source (Norris *et al.*, 2021), schedule (Marques *et al.*, 2024a), engagement, setting (Norris *et al.*, 2020), population (Wright *et al.*, 2025) and target behaviour (Schenk *et al.*, 2025a).

An advantage of both the TaTT and BCIO is that they are tools that can be improved through the feedback from users and the wider behaviour change community (Johnston *et al.*, 2021; Michie *et al.*, 2020; National Academies of Sciences, 2022). Up-to-date evidence about BCT-MoA links from the wider community can help improve the TaTT, making its mapping more nuanced with reference to relevant papers or databases (Johnston *et al.*, 2021). Similarly, feedback to the BCIO (e.g., regarding missing classes or definitions that need to be clarified) help these ontologies become more usable and widely applicable. This can be done by creating a "New Issue" on the ontology's GitHub (https://github.com/HumanBehaviourChangeProject/ontologies/issues). However, the potential for improving these tools is contingent on the behaviour change community actively using and critically engaging with them.

Use of the mapping between the BCIO and TaTT

Intervention developers may use the TaTT as a starting point for identifying links between BCTs and MoAs. After verifying these links are relevant for their target behaviour and specific context (e.g., through a literature search or stakeholder consultations), the BCTO and MoA Ontology can be used to identify more granular classes. This helps intervention developers and evaluators specify and investigate what specific MoA a BCT targets, providing clearer guidance. For example, a BCT can be linked more specifically to the MoA "belief about the positive social consequences" (BCIO:050608) instead of the more general MoA "belief about consequences" MoA. These classes, with their computer-readable IDs (URIs), can then be used when reporting the hypothesised BCT-MoA links in protocols and papers, facilitating study replication and the accumulation of evidence. An example workflow of using the TaTT alongside the BCIO to guide the intervention development is presented in Table 4.

To further illustrate the example presented in Table 4, intervention developers may identify "remembering to social distance" as a potential MoA for the target behaviour "adherence to physical distancing during Covid-19" in the UK. They may then use the TaTT, BCIO and the current mapping as follows:

- The developers map their MoA onto the TaTT MoAs, identifying **"Memory, Attention and Decision Processes"** as the relevant MoA grouping.
- From the TaTT-MoA Ontology mapping for "Memory, Attention and Decision Processes", the developers identify the relevant class to capture remembering to social distance: **"Memory" [*BCIO:050319*]**, thereby excluding

Table 4. Example workflow of using the TaTT, alongside BCIO mapping, during intervention development.

What is the behaviour that needs to change?	*Example: Adherence to physical distancing during Covid-19*
What MoA(s) could be targeted to change the behaviour?	*Example: remembering to maintain social distancing* • *In the TaTT, this MoA corresponds to "Memory, Attention, Decision Processes", which broadly captures several more different processes* • *The corresponding and relevant class in the MoA Ontology = Memory [BCIO:050319]*
What BCTs might change the behaviour?	*In the TaTT, suitable BCT links to the MoA are:* • *7.1. Prompts/cues* • *11.3. Conserving mental resources* *The corresponding classes in the BCT Ontology are:* • *Prompt intended action BCT [BCIO:007080]* • *Cue BCT [BCIO:007081]* • *Conserve mental resources BCT [BCIO:007134]*

the class ***"Decision-making" [BCIO:006116]*** which is not relevant for the MoA of interest

- Using the TaTT, the developers identify the following BCTs as potential links for "Memory, Attention and Decision Processes": "**7.1. Prompts/cues"** and **"13.1. Conserving mental energy"**.
    - For this example, we will assume that a literature search helps narrow down the selection to the BCT **"7.1. Prompts/cues"** to target remembering to social distance.
- From the TaTT-BCTO mapping for "7.1. Prompts/cues", the developers identify the corresponding and more precisely defined BCTs: "***Prompt intended action BCT" [BCIO:007080]*** and **"Cue BCT" [BCIO:007081].**
    - Based on the context and evidence, intervention designers select one of these BCTs, or where relevant, both. For the example, we will assume "***Prompt intended action BCT" [BCIO:007080]*** is more relevant.
- The identified BCTO and MoA Ontology classes (with their precise definitions and computer-readable IDs) are reported, alongside their TaTT counterparts, in the intervention development protocol and paper.

The developers may go on to evaluate their new intervention. Following this evaluation study, an additional step would be to provide feedback about a BCT-MoA link to the TaTT. This can be done by uploading the published paper to the relevant BCT-MoA link's "Resource" section. For example, this section for the "7.1 Prompts/cues (BCT)" and "Memory, attention & decision processes (MoA)" can be found in the following link and is shown in Figure 6: https://theoryandtechniquetool.humanbehaviourchange.org/tool/1116/resources).

Strengths and limitations

The current study supports better integration between the TaTT, which guides intervention development, and the BCIO, which supports precise reporting and evidence synthesis about behaviour change interventions. As the tools have been developed through different methods and for different purposes, the current work does not provide a one-to-one mapping between tools. Instead, users need to make judgements based on evidence when applying this mapping (e.g., to select more granular MoAs in the MoA Ontology). For the current mapping, our methods also relied on subjective judgements by researchers and consensus building among the wider research team. However, in the future, the mapping could be refined through feedback from TaTT and ontology users.

Beyond the links presented in the TaTT and this mapping, there are numerous additional links that could be proposed for the wider range of BCTs and MoAs in the ontologies. However, creating such a mapping between every BCT and MoA from the ontologies would be very time and resource intensive, and the resulting map is likely to be too detailed to be useable for practitioners. The current mapping provides a feasible way to engage with the more practical TaTT and the more detailed and precise ontologies. A final challenge in developing and maintaining the mapping is the need to update it whenever changes are made to the BCTO or MoA Ontology, as highlighted by current iterative methods.

Future directions

The current study provides a starting point for extending the TaTT to incorporate BCTs and MoAs from the BCIO, as part

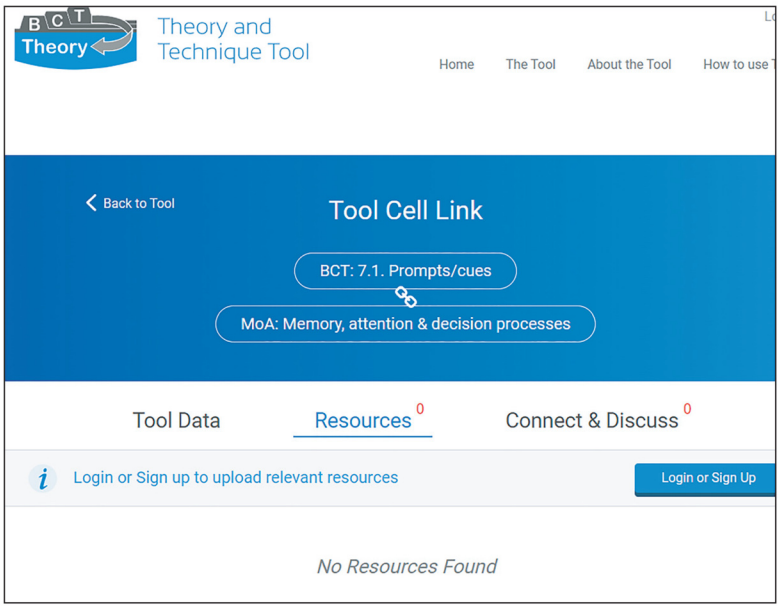

Figure 6. Screenshot of the Theory and Technique Tool (TaTT)'s resource section for a BCT-MoA link.

of the 5-year NIH-funded project, The Advancing Prevention Research in Cancer through Ontology Tools (APRICOT) Project (Michie *et al.*, 2024). This project is developing a series of tools and resources to extend the uses of ontologies in the behavioural and social sciences and make them more accessible and useable (Sharp *et al.*, 2023). The APRICOT Project will help keep this mapping current over the project's 5-year span, as well as develop the TaTT mapping using the BCIO to capture more detailed BCT-MoA links for specific target behaviours, such as physical activity.

Another area needing further development is the creation of improved measurements for MoAs (Cornelius *et al.*, 2024). This would allow us to test whether changes in specific MoAs, or combinations of them, actually bring about the effect of BCTs on behaviour. A previous study organised measures from a measurement repository by the Science of Behavior Change Network (SOBC; https://measures.scienceofbehaviorchange.org/) onto the 26 MoAs within the TaTT. (Cornelius *et al.*, 2023; Nielsen *et al.*, 2018). More recent efforts have focused on mapping these measurements to the more precise MoA Ontology classes, offering a clearer view of which MoAs each measurement targets (Cornelius *et al.*, 2024; Schenk *et al.*, 2025b). Since most measurements were linked to multiple MoAs, this work underscores the challenges in precisely measuring MoAs to whether interventions effectively modify specific MoAs to influence behaviour. To provide clearer guidance on how to test MoAs for each 'likely' BCT-MoA link, future work could attempt to: (1) collate and assess the quality of more precise measurements for specific MoAs, and/or (2) formally represent the combinations of classes from the MoA Ontology that measurements seem to assess.

Conclusion

The current mapping serves as a starting point for the work to integrate TaTT and BCIO, as part of the APRICOT project. This will facilitate more evidence-based intervention design, and precise and computer-readable reporting of BCT- MoA links. The online platforms of the TaTT and BCIO will facilitate collaborative use and development of the tools. As these tools are used more widely and user feedback is integrated into them, they can increasingly contribute to a stronger evidence base on BCTs, MoAs, and their links.

Ethics and consent

Ethical approval and consent were not required.

Data availability

Underlying data

No data associated.

Extended data

Open Science Framework: Human Behaviour-Change Project, https://doi.org/10.17605/OSF.IO/QRGC4 (West *et al.*, 2020).

This project contains the following extended data:

- The BCTO published in May, 2024; https://osf.io/ya74q
- The previous mapping of the BCTO classes onto the Theory and Techniques Tool's (TaTT) BCTs; https://osf.io/r7cux
- The MoA Ontology published in May, 2024; https://osf.io/pkq4e
- The previous mapping of the MoA Ontology classes onto the TaTT's MoA groups; https://osf.io/zmub5

OSF page for the Human Behaviour-Change Project; Homepage for all outputs across the project; https://osf.io/h4sdy/

Zenodo: HumanBehaviourChangeProject/ontologies: HumanBehaviourChangeProject/ontologies: Behaviour Change Technique Ontology, Mechanism of Action Ontology. https://doi.org/10.5281/zenodo.14882463 (Schenk *et al.*, 2025c)

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Open Peer Review

Current Peer Review Status: ✔ ✔ ✔

Version 2

Reviewer Report 18 November 2025

https://doi.org/10.21956/wellcomeopenres.27596.r137278

✔ **Chris Keyworth**
University of Leeds, Leeds, UK

Thank you for the opportunity to review this manuscript on linking behaviour change techniques and mechanisms of action by aligning the Theory and Techniques Tool with the BCIO. This is an interesting and very valuable approach that will be extremely useful for researchers and practitioners working in intervention development and evaluation. I have provided some comments below, which I hope are helpful.

General Comments

This study aimed to map the newer ontology categories to the TaTT's BCTs and MoAs, thereby creating an alignment between the TaTT and BCIO for better integration in intervention design and evaluation.

Unmapped BCTs - The paper notes that not all BCTs in the newer ontology could be mapped to the TaTT BCTs. Would it be helpful to clarify what this means in practice. Should these unmapped BCTs be disregarded? Are they considered outside the TaTT's scope? Some explanation of how users should interpret or handle these classes would strengthen the practical guidance.

Examples of MoAs - Where the manuscript states that the mapping supports intervention designers to "select, target and test their interventions' MoAs (e.g., motivation, capability, opportunity)," it may be helpful to include the some examples, such as those provided in the abstract e.g. skill development or access to resources, to make this more concrete.

Specific comments (mostly methodological)

p. 8

"For a class to be considered captured by a TaTT BCT, it needed to either (1) have a definition with the same meaning... or (2) include all the attributes..."

This is quite a specific coding rule. Was this definition from existing literature, or was it developed by the research team for this study?

p. 9

"Four new classes were added."

Does this refer to classes of BCTs?

p. 10

"For a class to be considered as captured by an MoA..."

Similarly, it would be helpful to explain whether this coding rule was informed by prior research or

developed internally by the team.

p. 10
“This approach differed from how we mapped BCTs…”
I found this a little difficult to follow. Including one or two brief examples here, as you do in the subsequent sentences, would make the distinction clearer.
Reliability / agreement - The manuscript reports that independent coding was conducted and disagreements were resolved through discussion. Were any coder agreement metrics calculated? Formal reliability statistics may not be essential for this type of conceptual mapping, if any initial coder agreement (e.g., percentage overlap) was caried out it might be useful to document.
p. 19
“Some disagreements arose…”
A brief indication of the general nature of these disagreements (e.g., conceptual boundaries, hierarchical placement) would help readers understand the complexity of the task.
Regarding “Minor changes were made to the MoA Ontology… Three classes were added…” - It may be useful to explicitly state whether these three added classes constitute all the “minor changes” referenced, and briefly summarise the rationale for each addition, to make the revision process more transparent.

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: Health psychology / behavioural 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 08 November 2025

https://doi.org/10.21956/wellcomeopenres.27596.r137027

Mor Peleg
University of Haifa, Haifa, Israel

I thank the authors for their thoughtful and elaborate response.

I understand now that the aim was not to formalise the TaTT using ontological expressions. The TaTT is used in practical contexts, often for intervention development, or for understanding interventions theoretically. Accordingly, the mapping to the BCIO is intended to help behavioural and social scientists report BCTs and MoAs more precisely and formally, where relevant, particularly in protocols and papers about behaviour change interventions.

Based on this explanation, almost all of my comments were resolved.
26, 28. Thank you for making the change – it is now resolved

Only one outstanding comment remains, related to my previous Comment #2. I suggested that the author add the following sentence (copied from their response letter) to the paper itself: "In order to make TaTT a practical tool that is useful to a wide range of people studying behaviour, the authors did not use formal ontological language in describing BCTs or MoAs."

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: biomedical ontologies, knowledge representation, mobile health, computer-interpretable clinical guidelines, clinical decision-support systems

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 28 May 2025

https://doi.org/10.21956/wellcomeopenres.26345.r122374

Elin M Andersson
Department of Public Health and Clinical Medicine, Umea University, Umeå, Sweden

To aid researchers and practitioners in selecting behaviour change techniques (BCTs) that effectively target specific mechanisms of actions (MoAs), the **Theory and Technique Tool (TaTT)** was previously developed. This tool offers a matrix indicating which BCTs are likely—or unlikely—to influence particular MoAs. More recently, as part of The Behaviour Change Intervention Ontology, the two ontologies of the **Behaviour Change Technique Ontology (BCTO)** and the **Mechanisms of Action Ontology (MoA Ontology)** have been introduced. These ontologies expand the range of BCTs and MoAs, offering more precise, standardised, and machine-readable definitions.

The aim of this study was to enhance the utility of the TaTT by aligning it with the above-mentioned ontologies. Potentially, this could:

1. Enabling ontology users to formulate hypotheses about likely BCT–MoA relationships.
2. Helping TaTT users to identify more detailed and relevant BCTs and MoAs for intervention design and research.

Introduction: The introduction provides a summary of previous work of relevance for this study, and outline the development of the TaTT, the BCTO and the MoA. I find that the level of detail is well-balanced; the text gives an overview and is clear and easy to follow, and the relevant references describing this rigorous work more in detail is included. I also believe the included figures should be helpful for readers without previous experience of the TaTT.

Method: The steps taken are clearly described. However, I struggled with this sentence: “Unlike the BCT mapping, the researchers did not record multiple different TaTT MoAs for a single class from the MoA Ontology.” To me, the formulation is confusing, but the example that follows clarifies.

Results: The tables are easy to read and search through. When this is further developed, perhaps the Tool Cell Link in the TaTT, (including the chosen specified BCT and Moa) could be expanded to also include the corresponding BCTO- and MoA classes? I realize that this would make the website more difficult to read, but perhaps a solution would be to make the BCT and the MoA in the Tool Cell Link clickable (so that the ontology classes are shown only for users who wish to see them). I believe that the suggested workflow of using the TaTT alongside BCIO mapping during intervention (presented in the discussion) could be facilitated if the link to the ontologies is built into the TaTT. Perhaps this is already planned?

Discussion: The discussion includes several important considerations. The importance of that the mapping is applied with flexibility, considering evidence about target behaviours, populations and the context; Furthermore, that the potential for improving these tools is contingent on the behaviour change community actively using and critically engaging with them, including also to provide feedback about BCT-MoA-links; The need of improved measurements for MoA is also pointed out.

I appreciate the opportunity to review this study, not least since I, alongside other colleagues, hoped for that the TaTT would be updated when the BCIO was launched. This study is definitely an important starting point for the work of integrating the TaTT and BCIO.

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; CVD prevention; Lifestyle modification; Risk communication; Efficacy beliefs

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.

Author Response 26 Sep 2025

Paulina Margarete Schenk

Reviewer 2: *To aid researchers and practitioners in selecting behaviour change techniques (BCTs) that effectively target specific mechanisms of actions (MoAs), the **Theory and Technique Tool (TaTT)** was previously developed. This tool offers a matrix indicating which BCTs are likely—or unlikely—to influence particular MoAs. More recently, as part of The Behaviour Change Intervention Ontology, the two ontologies of the **Behaviour Change Technique Ontology (BCTO)** and the **Mechanisms of Action Ontology (MoA Ontology)** have been introduced. These ontologies expand the range of BCTs and MoAs, offering more precise, standardised, and machine-readable definitions.*

The aim of this study was to enhance the utility of the TaTT by aligning it with the above-mentioned ontologies. Potentially, this could:

1. *Enabling ontology users to formulate hypotheses about likely BCT–MoA relationships.*
2. *Helping TaTT users to identify more detailed and relevant BCTs and MoAs for intervention design and research.*

Response: We thank the reviewer for engaging with this work and providing feedback on this manuscript.

Reviewer 2: *Introduction: The introduction provides a summary of previous work of relevance for this study, and outline the development of the TaTT, the BCTO and the MoA. I find that the level of detail is well-balanced; the text gives an overview and is clear and easy to follow, and the*

relevant references describing this rigorous work more in detail is included. I also believe the included figures should be helpful for readers without previous experience of the TaTT.
Response: We thank the reviewer for their positive feedback on the Introduction.

Reviewer 2: *Method: The steps taken are clearly described. However, I struggled with this sentence: "Unlike the BCT mapping, the researchers did not record multiple different TaTT MoAs for a single class from the MoA Ontology." To me, the formulation is confusing, but the example that follows clarifies.*
Response: We thank the reviewer for their feedback. The relevant passage has been updated to improve clarity:

- "*The researchers did not do the reverse mapping, i.e., mapping TaTT MoAs to specific classes in the MoA Ontology. This approach differed from how we mapped BCTs, where it sometimes made sense to group several TaTT BCTs under broader classes in the BCTO. We avoided this here, because the TaTT MoAs are often very broad and can include subcomponents that belong to different parts of the MoA Ontology's hierarchy. As a result, many TaTT MoAs would only map onto high-level structural classes (e.g., "mental disposition"), which are too broad to be practically meaningful. For example, the TaTT MoA "Social/Professional role & identity" includes the MoAs "personal role" [BCIO:006081] and "identity" [ADDICTO:0000381]. Since these are not closely related in the ontology's logical hierarchy, the only possible mapping would be to a very general class such as "characteristic" [BFO:0000020] in the BCIO.* Therefore, to be more useable, the mapping between these tools was kept simpler."

Reviewer 2: *Results: The tables are easy to read and search through. When this is further developed, perhaps the Tool Cell Link in the TaTT, (including the chosen specified BCT and Moa) could be expanded to also include the corresponding BCTO- and MoA classes? I realize that this would make the website more difficult to read, but perhaps a solution would be to make the BCT and the MoA in the Tool Cell Link clickable (so that the ontology classes are shown only for users who wish to see them). I believe that the suggested workflow of using the TaTT alongside BCIO mapping during intervention (presented in the discussion) could be facilitated if the link to the ontologies is built into the TaTT. Perhaps this is already planned?*
Response: We thank the reviewer for their suggestion. We are internally considering how best to integrate the results in a user-friendly way into the TaTT user interface.

Reviewer 2: *The current suggestion will be shared with the wider team and considered with the website developers to signpost the relevant classes from the ontologies for each BCT and MoA in the TaTT. Discussion: The discussion includes several important considerations. The importance of that the mapping is applied with flexibility, considering evidence about target behaviours, populations and the context; Furthermore, that the potential for improving these tools is contingent on the behaviour change community actively using and critically engaging with them, including also to provide feedback about BCT-MoA-links; The need of improved measurements for MoA is also pointed out.*
Response: We thank the reviewer for their positive feedback on the Discussion.

Reviewer 2: *I appreciate the opportunity to review this study, not least since I, alongside other colleagues, hoped for that the TaTT would be updated when the BCIO was launched. This study is definitely an important starting point for the work of integrating the TaTT and BCIO* **Response:** We thank the reviewer for their interest in the BCIO and the TaTT and their help in

improving this paper.

Competing Interests: No competing interests were disclosed.

Reviewer Report 29 April 2025

https://doi.org/10.21956/wellcomeopenres.26345.r122365

Mor Peleg
University of Haifa, Haifa, Israel

Many studies use behavior-change techniques (BCT) to facilitate behavior change. To allow the scientific community to compare different tools and systems related to behavior change, it is vital that studies relate to theories of behavior in a standard way; scientists should report the systems and their evaluation studies by referring to a standardized set of BCTs and the mechanisms of action (MoA) through which interventions bring about their influence on behaviour) to understand causal processes behind interventions. Two knowledge sources/tools have been created to facilitate such standardization: the TaTT and the BCI Ontology (BCIO). These resources conceptualize complementary and overlapping knowledge, yet they have not been mapped before. By mapping them, developers of BC Interventions could be facilitated by using the TaTT to and then using the mappings to the BCIO to hypothesise potential links between the extended number of BCTs and MoAs found in the BCIO. This could allow researchers to identify and report the more detailed, clearly defined ontology classes in their protocols and papers and could link the papers to the TaTT.

Detailed comments:
Clarity
1) "Clicking on any cell reveals the evidence for the relevant link from the three studies".
I tried to click on the green cell that is discussed on p. 6: link between BCT “1.2 Problem Solving” and the MoA “BaCa”, which stands for the “Belief about Capabilities".
I was expecting to see an explanation about the evidence. Instead I saw just metadata:
- Triangulation study: study not required
I was expecting to see some explanation why this link exists. Instead, I had to manually follow a link to the 2 studies (literature study and expert panel). Then to search for this link there. I saw that the expert study did not include any explanations for why they think the links exist. As a person trained in informatics and not in psychology, it would have been very helpful to me, if the TaTT would provide an explanation when I clicked on a green square for why links exists. I don't consider the fact that the studies found such links as an explanation. An explanation could cite from the literature study the basis for the link. However, the literature study also did not provide such an example. It would be useful to add examples to the TATT for green cells. For the example above, you could add that BCT1.2 could help a user solve a problem that she has related to

barriers that she perceives to performing the behavior via the MoA of change in the belief about capabilities.

2) Please note though, that I don't understand why in the TaTT, belief about capabilities is a MoA. It is a belief, a disposition, and this is correctly reflected in the BCIO as such. The MoA should be "change in belief".

3) " by starting off with a TaTT MoA (e.g., “Memory, attention and decision process”) and then identifying the corresponding detailed ontology classes (e.g., “memory process” and “attending”), TaTT users can report more nuanced and varied evidence about BCT-MoA links or lack thereof"
>> I don't understand how you would create an ontological expression that ties both ontology classes in a logical way. I also think that the part about decision process is not there. As in the comment above, memory_process and attending are both mental processes; they are not MoA. I guess that you meant that an expression should be created "Mechanism_of_action_through_bodily_process" and 'through' some (memory_process OR mental_process)? On the other hand you say that users of TaTT find the ontology difficult to use and prefer to use TaTT. So I don't understand what value they would get from the ontology if they don't use the ontology for writing ontological expressions. What value would they get if they would know that some of the related classes in the ontology are Attending and Memory_process?

Methods
4) "In cases where a class did not align with a single TaTT BCT/MoA, the researchers recorded multiple TaTT BCTs/MoAs for the class, as needed."
>>In my opinion it is not enough to just list classes that are needed to be composed; a class expression needs to be formulated by composing the classes via logical descriptions that are syntactically and semantically correct.
I recommend including another step in the methods, which is the coding of the description logics class expressions in the ontology that convey the meaning of the TaTT MoAs and BCTs.
In the comments below I used the structure of 'Class-I' 'Class-J' as a shorthand notation for expressions of the form:
Class-I and relationship some Class-J

5) "Unlike the BCT mapping, the researchers did not record multiple different TaTT MoAs for a single class from the MoA Ontology".
> I don't understand: did you mean that there could be a 1:1 or a 1:N but not N:1 or N:M relations between TaTT MoAs and ontology-MoA class?

6) I suggest adding annotation properties to the BCT and MoA classes in the ontologies that state which TaTT class is mapped to the BCT or MoA class. This should be true for 1:1 mappings but also for class descriptions added to represent complex MoAs.

Results
7) I think that mechanism of action is a process rather than a disposition. Many (all?) of your mappings from TaTT MoA are to (ontological) dispositions. Instead, I think that the modeling should be: mechanism of action (process) can be through a bodily disposition.

8) I think that the mapping of TaTT 'Social/Professional role & identity' should be represented in the following way:

‘mechanism of action through personal role’ ‘personal role’
OR
'mechanism of action through cognitive representation' ‘self-identity'

9) Similarly for belief, use 'mechanism of action through bodily disposition' belief

10) I don't understand why in the MoA, self-efficacy belief for a behaviour and its associated outcomes is not a subclass of self-efficacy belief for a behaviour
I suggest the following hierarchy (note lines 2 and 3 below)
self-efficacy belief
  self-efficacy belief for a behaviour
    self-efficacy belief for a behaviour and its associated outcomes
    situational self-efficacy belief for a behaviour
      self-efficacy belief for a behaviour in the face of social pressure
      self-efficacy belief for a behaviour under conditions of stress
    behavioural recovery self-efficacy
    behaviour maintenance self-efficacy
    self-efficacy belief for a behaviour during routine activities
  self-efficacy belief for avoiding a threat

11) I disagree with the mapping of the Optimism TaTT MoA to the following two MoA ontology classes:
Belief about likelihood of consequences of an occurrence [BCIO:006026]
>> here there is nothing about a positive consequence
Evaluative belief [BCIO:006038]: A about whether a particular aspect of the world is positive or negative.
>> Perhaps there is a way to formulate a class expression that captures the correct mapping by referring to these 2 classes and to the value "positive". Also, to be a mechanism of action, I think that you should use the process "evaluative belief formation about a behaviour" BCIO:050650 rather than use belief, which is a disposition

12) Reinforcement (TaTT)
'mechanism of action through reinforcement process' 'reinforcement process'
With a similar structure you can represent:
'mechanism of action through bodily process' 'Internal reward for a response'
However, this has an additional semantics compared to the TaTT reinforcement so please justify.

13) Intention [TaTT]:
'mechanism of action through bodily disposition' 'Behavioural intention'

14) Goals [TaTT]:
'mechanism of action through cognitive representation' Goal

15) Memory, attention & decision processes
>> See comment 3 above

16) Environmental context & resources:

'mechanism of action through environmental disposition' 'environmental disposition'
I don't think that you need the Environmental System class, because the (textual) definition of 'environmental disposition' is: "A which is realised by an environmental system or system parts thereof"

17) Social Influences
'mechanism of action through bodily process' 'Socially-related behaviour'
'mechanism of action through bodily process' 'Interpersonal process'

18) Emotion
'mechanism of action through bodily process'
19) Behavioural regulation
'mechanism of action through bodily process' Isn't this enough? Please justify why you also need:
'mechanism of action through bodily disposition
20) Norms
'mechanism of action through bodily process' Why do you need Social representation of a behaviour? Given that 'normative behaviour'
Is-a 'socially-related behaviour'?
'mechanism of action through social group attribute' 'Group descriptive behavioural norm'
'mechanism of action through social group attribute' 'Group evaluative behavioural norm'

21) Subjective norms >> See 9 above

22) Attitude towards the behaviour
'mechanism of action through bodily disposition' 'Attitude' (or one of its subclasses)
'mechanism of action through bodily disposition' 'evaluative belief '

23) Motivation
'mechanism of action through bodily process' 'Behavioural motivation'

24) Self-image:
Belief – see 9 above
Identity – see 8 above

25) Needs, Values
>> as above, use with 'mechanism of action through bodily process'

26) Feedback processes
'mechanism of action through bodily process' 'Social comparison process'
'mechanism of action through bodily process' 'Mentally comparing against a standard'
**please explain how you could link 'Feedback process to a person' to one of the mechanism of actions of the ontology. I'm not sure how to do it.

27) Social learning/imitation
'mechanism of action through bodily process' 'Observational learning'

28) Behavioural cueing
Stimulus is a direct child of Entity in BCIO.

**please explain how you could link it to one of the mechanism of actions of the ontology. I'm not sure how to do it.

29) General attitudes/beliefs
>> See above RE: beliefs, attitudes

30) Perceived susceptibility/vulnerability
>> See above RE: beliefs, attitudes

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?
Partly

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?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: biomedical ontologies, knowledge representation, mobile health, computer-interpretable clinical guidelines, clinical decision-support systems

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 26 Sep 2025

Paulina Margarete Schenk

Reviewer 1: *Many studies use behavior-change techniques (BCT) to facilitate behavior change. To allow the scientific community to compare different tools and systems related to behavior change, it is vital that studies relate to theories of behavior in a standard way; scientists should report the systems and their evaluation studies by referring to a standardized set of BCTs and the mechanisms of action (MoA) through which interventions bring about their influence on behaviour) to understand causal processes behind interventions. Two knowledge sources/tools have been created to facilitate such standardization: the TaTT and the BCI Ontology (BCIO). These*

resources conceptualize complementary and overlapping knowledge, yet they have not been mapped before. By mapping them, developers of BC Interventions could be facilitated by using the TaTT to and then using the mappings to the BCIO to hypothesise potential links between the extended number of BCTs and MoAs found in the BCIO. This could allow researchers to identify and report the more detailed, clearly defined ontology classes in their protocols and papers and could link the papers to the TaTT. **Response:** We thank the reviewer for engaging with the work in detail and appreciate their time in providing feedback to this paper.

Reviewer 1*: Detailed comments:*
Clarity
1) "Clicking on any cell reveals the evidence for the relevant link from the three studies".
I tried to click on the green cell that is discussed on p. 6: link between BCT "1.2 Problem Solving" and the MoA "BaCa", which stands for the "Belief about Capabilities".
I was expecting to see an explanation about the evidence. Instead I saw just metadata:
- Triangulation study: study not required
I was expecting to see some explanation why this link exists. Instead, I had to manually follow a link to the 2 studies (literature study and expert panel). Then to search for this link there. I saw that the expert study did not include any explanations for why they think the links exist. As a person trained in informatics and not in psychology, it would have been very helpful to me, if the TaTT would provide an explanation when I clicked on a green square for why links exists. I don't consider the fact that the studies found such links as an explanation. An explanation could cite from the literature study the basis for the link. However, the literature study also did not provide such an example. It would be useful to add examples to the TATT for green cells. For the example above, you could add that BCT1.2 could help a user solve a problem that she has related to barriers that she perceives to performing the behavior via the MoA of change in the belief about capabilities. **Response:** We thank the reviewer for their feedback on the level of detail included in the Theories and Techniques Tool (TaTT) regarding specific links. In line with the reviewer's comments, the relevant sentence has been updated to be more precise in the manuscript's Introduction (p. 6):

- *"Clicking on any cell reveals the meta-data about the relevant link from the three studies. However, for precise information on evidence regarding the links, the original studies should be referred to (Carey et al., 2019; Connell et al., 2019; Johnston et al., 2018, 2021)."*

We appreciate the feedback on the TaTT itself and will share this with the wider team. Details for what qualifies as a link within the expert consensus study is outlined by Connell et al., (2019), namely that 80% or more of participating experts needed to agree to a link. The TaTT did not set out to be explanatory, just to reflect the links between BCTs and MoAs that were hypothesised to be the case by experts as reported in the literature and in an expert consensus study. As the current work focused on mapping the TaTT and BCIO, updating the TaTT and how evidence is presented within it is beyond the scope of this work.
Reviewer 1: *2) Please note though, that I don't understand why in the TaTT, belief about capabilities is a MoA. It is a belief, a disposition, and this is correctly reflected in the BCIO as such. The MoA should be "change in belief".* **Response:** We appreciate the reviewer's comment. As suggested, in an intervention, a change in belief could constitute a mechanism of action (MoA). Here, 'change' also includes maintaining a belief at a level different from what it would have been without the intervention. The TaTT includes potential MoAs that can be influenced as part of an intervention. If an intervention successfully changes, for example, beliefs about capability, then (as the reviewer suggested) this change process would qualify

as an MoA of that intervention. In behavioural science, it is useful to discuss constructs, such as beliefs about capability, as potential MoAs, since they represent targets for change. Particularly in the way that the TaTT is conceptualised, which links BCTs with 'likely' MoAs, there is an implication that constructs would be expected to change if they serve as the MoAs through which a BCT works. We have added the following clarification under the paragraph that introduces MoAs in the Introduction section:

- "*While MoAs are processes through which interventions work to change behaviour, we often refer to states or dispositions (e.g., beliefs rather than changing or maintaining beliefs) as MoAs in behavioural sciences. In this paper, we use similar language for brevity, but each time we refer to an MoA, it should be understood as either an MoA or a key construct that can be influenced and is part of an intervention's MoA*."

For clarity, the Introduction on the TaTT section has also been amended to be clearer and refer to 'potential MoAs':

- "*To provide practical guidance on selecting BCTs to target **potential** MoAs in interventions, an online evidence-based grid that shows 'likely' BCT-MoA links [1] , the Theory and Technique Tool (TaTT**)**, was developed. These links were between 74 BCTs selected from the 93 BCTs of the Behaviour Change Techniques Taxonomy v1 (BCTTv1; Michie et al., 2013) and 26 **potential** MoAs. The 74 BCTs were the most commonly occurring ones, from the 93 BCTs, in a literature review (Carey et al., 2019).*"

The MoA Ontology's upper level includes classes that formally represent "MoA through entity x." Other high-level classes, such as "bodily disposition," are related to classes explicitly formulated as MoAs (e.g., "MoA through bodily disposition"). In the paper describing the MoA Ontology, we explain that subclasses, such as "belief about capability", are treated as MoAs through their hierarchical relationships. This approach avoids the need for a more complex hierarchy in which every class would be explicitly defined as "MoA through entity x" and separate classes would also be created for each "entity x." However, we have now logged an issue on the GitHub issue tracker for the Behaviour Change Intervention Ontology on whether we will add 'through' relationships to each entity that qualifies as a potential MoA in the MoA Ontology (see https://github.com/HumanBehaviourChangeProject/ontologies/issues/1107). In order to make TaTT a practical tool that is useful to a wide range of people studying behaviour, the authors did not use formal ontological language in describing BCTs or MoAs. The MoA Ontology is more appropriate for contexts where formal language is required.

Reviewer 1: *3) " by starting off with a TaTT MoA (e.g., "Memory, attention and decision process") and then identifying the corresponding detailed ontology classes (e.g., "memory process" and "attending"), TaTT users can report more nuanced and varied evidence about BCT-MoA links or lack thereof"*
>> I don't understand how you would create an ontological expression that ties both ontology classes in a logical way. I also think that the part about decision process is not there. As in the comment above, memory_process and attending are both mental processes; they are not MoA. I guess that you meant that an expression should be created "Mechanism_of_action_through_bodily_process" and 'through' some (memory_process OR mental_process)? On the other hand you say that users of TaTT find the ontology difficult to use and prefer to use TaTT. So I don't understand what value they would get from the ontology if they don't use the ontology for writing ontological expressions. What value would they get if they would know that some of the related classes in the ontology are Attending and Memory_process?

Response: We thank the reviewer for their comment on this. The feedback is on an example provided on how to use the BCIO (more specifically the MoA Ontology) to complement the TaTT when reporting a potential MoAs with more detail. To describe this example more precisely, the relevant sentence has been updated to read as follows:

- "*For example, TaTT users could start off by identifying a TaTT MoA (e.g., "Memory, attention and decision process") and then the corresponding detailed ontology classes for the potential MoA of interest (e.g., using the "memory process" class to specify the MoA more granularly where relevant). This would allow them to report more nuanced and varied evidence about BCT-MoA links or lack thereof."*

Please note that, in the relevant extract and the current work more broadly, we did not aim to create ontological expressions for the TaTT MoAs (e.g., "Memory, attention and decision-making") but provide an example of how the current mapping to the BCIO can be used for more precise reporting in conjunction with the TaTT.

Reviewer 1: *Methods*
4) "In cases where a class did not align with a single TaTT BCT/MoA, the researchers recorded multiple TaTT BCTs/MoAs for the class, as needed."
>>In my opinion it is not enough to just list classes that are needed to be composed; a class expression needs to be formulated by composing the classes via logical descriptions that are syntactically and semantically correct.
I recommend including another step in the methods, which is the coding of the description logics class expressions in the ontology that convey the meaning of the TaTT MoAs and BCTs.
In the comments below I used the structure of 'Class-I' 'Class-J' as a shorthand notation for expressions of the form:
Class-I and relationship some Class-J **Response:** Thank you for the suggestion. As the TaTT MoAs are very broad (e.g., "Memory, attention and decision-making") and often include MoAs that do not share upper-level classes within the MoA Ontology, we suggest that the current mapping serves as a practical tool for using the BCIO and TaTT together, where appropriate. At this stage, the aim was not to formalise the TaTT using ontological expressions. The TaTT is used in practical contexts, often for intervention development, or for understanding interventions theoretically. Accordingly, the mapping is intended to help behavioural and social scientists report BCTs and MoAs more precisely and formally, where relevant, particularly in protocols and papers about behaviour change interventions. This can also be used to integrate evidence accumulated with both of these tools.
Reviewer 1: *5) "Unlike the BCT mapping, the researchers did not record multiple different TaTT MoAs for a single class from the MoA Ontology".*
> I don't understand: did you mean that there could be a 1:1 or a 1:N but not N:1 or N:M relations between TaTT MoAs and ontology-MoA class? **Response:** Thank you for noting this; the description needed to be updated to be clearer. This extract, along with the broader explanation in the paragraph, aimed to convey that mapping the TaTT MoAs onto specific MoA Ontology classes would not for practical application. These TaTT MoAs are very broad and sometimes do not share a meaningful 'parents' in the MoA Ontology; therefore, they would be mapped onto very broad structural classes in the ontology. The relevant passage has been updated to improve clarity:

- "*The researchers did not do the reverse mapping, i.e., mapping TaTT MoAs to specific classes in the MoA Ontology. This approach differed from how we mapped BCTs, where it sometimes made sense to group several TaTT BCTs under broader classes in the BCTO. We*

avoided this here, because the TaTT MoAs are often very broad and can include subcomponents that belong to different parts of the MoA Ontology's hierarchy. As a result, many TaTT MoAs would only map onto high-level structural classes (e.g., "mental disposition"), which are too broad to be practically meaningful. For example, the TaTT MoA "Social/Professional role & identity" includes the MoAs "personal role" [BCIO:006081] and "identity" [ADDICTO:0000381]. Since these are not closely related in the ontology's logical hierarchy, the only possible mapping would be to a very general class such as "characteristic" [BFO:0000020] in the BCIO. Therefore, to be more useable, the mapping between these tools was kept simpler."

Reviewer 1: *6) I suggest adding annotation properties to the BCT and MoA classes in the ontologies that state which TaTT class is mapped to the BCT or MoA class. This should be true for 1:1 mappings but also for class descriptions added to represent complex MoAs.*
Response: For the BCTs, the TaTT BCTs (with one-to-one mapping to the BCTO classes) are already cross referenced within the BCTO. This is now explicitly indicated in the manuscript:

- "The BCTs from the TaTT that have one-on-one mappings with BCTO classes are also cross-referenced within the ontology."

As suggested, we have added the potential MoAs from the TaTT as relevant examples to the MoA Ontology when a one-to-one mapping exists (e.g., the example ""Knowledge" from the Theory and Techniques Tool (https://theoryandtechniquetool.humanbehaviourchange.org/tool)" has been added for the class "knowledge" [BCIO:006052] in the MoA Ontology). This is also indicated now in the manuscript:

- "*The TaTT MoAs that have one-on-one mappings with classes in the MoA Ontology were explicitly included as examples in the ontology*."

However, as indicate above, the mapping of very broad TaTT MoAs to single MoA Ontology is often not meaningful in practice and so these TaTT MoAs have not been added as examples to the ontology at this point.
Reviewer 1: *Results*
7) I think that mechanism of action is a process rather than a disposition. Many (all?) of your mappings from TaTT MoA are to (ontological) dispositions. Instead, I think that the modeling should be: mechanism of action (process) can be through a bodily disposition. **Response:** As the reviewer suggested, mechanisms of action are processes, rather than dispositions. As also indicated above, the TaTT MoAs would only count as MoAs when they are part of a process through which the intervention works to influence behaviour. We have added the following clarification under the paragraph introducing MoAs in the Introduction:

- "*While MoAs are processes through which interventions work to change behaviour, we often refer to states or dispositions (e.g., beliefs rather than changing or maintaining beliefs) as MoAs in behavioural sciences. In this paper, we use similar language for brevity, but each time we refer to an MoA, it should be understood as either an MoA or a key construct that can be influenced and is part of an intervention's MoA*."

In the MoA Ontology, we include the formal structure "MoA through class x," where class x refers to higher-level classes within the MoA Ontology. These upper-level MoA classes are formally linked to related classes. The idea is that lower-level classes are considered MoAs through this relationship and their hierarchical relationship. This approach was chosen during the development of the MoA Ontology to efficiently represent that MoAs can operate through various entities, including dispositions such as beliefs, without duplicating the

hierarchy. We have now also raised an issue on GitHub to discuss whether we more precisely capture these lower-level classes by adding a 'through' relationship between them and the formal mechanism of action class (see https://github.com/HumanBehaviourChangeProject/ontologies/issues/1107). On the other hand, the TaTT is not an ontology and so does not follow the same structure. Potential MoAs or constructs that are part of MoAs are often referred to as MoAs within behavioural sciences. Within the TaTT, the influence on the constructs (e.g., belief about capability) is implied, as a BCT would be working through this construct (i.e., changing it) to influence behaviour.

Reviewer 1: *8) I think that the mapping of TaTT 'Social/Professional role & identity' should be represented in the following way:*
'mechanism of action through personal role' 'personal role'
OR
'mechanism of action through cognitive representation' 'self-identity' **Response:** We appreciate the recommendation. However, to avoid creating confusion for behavioural and social scientists, we would suggest keeping the mapping simpler, for example, only using the classes 'personal role' and 'self-identity'. Within the MoA Ontology, these classes are linked to the relevant formal MoA class either directly or through their parent classes. As explained above, this approach can be used to capture MoAs more efficiently. The upper levels might be confusing to users who are unfamiliar with the formal language of ontologies and have limited time to engage with the MoA Ontology. However, as noted, we are considering adding the 'through' relationship to the more detailed classes in the MoA Ontology to make their link to the upper-level MoA class more explicit.

Reviewer 1: *9) Similarly for belief, use 'mechanism of action through bodily disposition' belief*
Response: As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.
Reviewer 1: *10) I don't understand why in the MoA, self-efficacy belief for a behaviour and its associated outcomes is not a subclass of self-efficacy belief for a behaviour*
I suggest the following hierarchy (note lines 2 and 3 below)
self-efficacy belief
self-efficacy belief for a behaviour
self-efficacy belief for a behaviour and its associated outcomes
situational self-efficacy belief for a behaviour
self-efficacy belief for a behaviour in the face of social pressure
self-efficacy belief for a behaviour under conditions of stress
behavioural recovery self-efficacy
behaviour maintenance self-efficacy
self-efficacy belief for a behaviour during routine activities
self-efficacy belief for avoiding a threat
Response: The class 'self-efficacy belief about a behaviour and its associated behaviour' has part 'self-efficacy belief about a behaviour' but is not strictly speaking a subclass of the latter. This relationship is indicated in the MoA Ontology. Please note that any feedback regarding the MoA Ontology and the structure of its classes can be submitted through the issue tracker on GitHub:
https://github.com/HumanBehaviourChangeProject/ontologies/issues

Reviewer 1: *11) I disagree with the mapping of the Optimism TaTT MoA to the following two MoA ontology classes:*
Belief about likelihood of consequences of an occurrence [BCIO:006026]
>> here there is nothing about a positive consequence
Evaluative belief [BCIO:006038]: A about whether a particular aspect of the world is positive or negative.
>> Perhaps there is a way to formulate a class expression that captures the correct mapping by referring to these 2 classes and to the value "positive". Also, to be a mechanism of action, I think that you should use the process "evaluative belief formation about a behaviour" BCIO:050650 rather than use belief, which is a disposition **Response:** The definition of 'Optimism' ("Confidence that things will happen for the best or that desired goals will be attained") captures the likelihood of an event and that this will be positive. However, the research team would recommend keeping the two classes mapped onto 'Optimism' broad as it can also involve beliefs that negative events are unlikely. We have added a clarification to the 'Optimism' that the combination of the two classes mapped to 'Optimism' are necessary to capture it:

- "** *To capture 'Optimism' a combination of 'belief about likelihood of consequences of an occurrence [BCIO:006026]' and 'evaluative belief [BCIO:006038]' are needed, as optimism involves beliefs about likelihoods and an evaluative component. It should be noted that 'Optimism' can involve beliefs that negative events are unlikely."*

Reviewer 1: *12) Reinforcement (TaTT)*
'mechanism of action through reinforcement process' 'reinforcement process'
With a similar structure you can represent:
'mechanism of action through bodily process' 'Internal reward for a response'
However, this has an additional semantics compared to the TaTT reinforcement so please justify.
Response: As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *13) Intention [TaTT]:*
'mechanism of action through bodily disposition' 'Behavioural intention' **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *14) Goals [TaTT]:*
'mechanism of action through cognitive representation' Goal **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *15) Memory, attention & decision processes*
>> See comment 3 above **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *16) Environmental context & resources:*
'mechanism of action through environmental disposition' 'environmental disposition'
I don't think that you need the Environmental System class, because the (textual) definition of 'environmental disposition' is: "A which is realised by an environmental system or system parts thereof" **Response:** We agree that any MoA working through the environmental system is likely to relate to environmental dispositions (realised as processes). However, the MoA Ontology aimed to capture constructs that are often used in behavioural sciences, which includes both the environmental systems and dispositions or opportunities within these environments. Depending on how an MoA is conceptualised and operationalised in an intervention, it can involve the actual environment being changed (e.g., more walking pathways in the environment) or the disposition in the environment (e.g., the accessibility of an environment). While these are often overlapping and closely related, we lean towards representing both entities as classes for now. Regarding the second point of adding the higher-level classes in the MoA Ontology, please note the explanations provided above: We would like to continue using the simple approach to capturing these MoAs, as this can enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *17) Social Influences*
'mechanism of action through bodily process' 'Socially-related behaviour'
'mechanism of action through bodily process' 'Interpersonal process' **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *18) Emotion*
'mechanism of action through bodily process' **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.
Reviewer 1: *19) Behavioural regulation*
'mechanism of action through bodily process' Isn't this enough? Please justify why you also need: 'mechanism of action through bodily disposition **Response:** On the first note – adding the upper-level classes in the MoA Ontology – please note the explanations above about attempting to keep this mapping simple. The class 'self-regulatory capability' (a disposition) has been mapped to the TaTT 'Behavioural regulation' (definition: "Behavioural, cognitive and/or emotional skills for managing or changing behaviour."), as the part of the definition on 'skills' would include capabilities.
Reviewer 1: *20) Norms*
'mechanism of action through bodily process' Why do you need Social representation of a behaviour? Given that 'normative behaviour'
Is-a 'socially-related behaviour'?
'mechanism of action through social group attribute' 'Group descriptive behavioural norm'
'mechanism of action through social group attribute' 'Group evaluative behavioural norm'
Response: As norms can include representations or beliefs held by a group ('Norms' in the TaTT is defined as "The attitudes held and behaviours exhibited by other people within a social group"), we mapped the classes "social representation of a behaviour [BCIO:050779]"

and “group belief [BCIO:050669]”, among others onto this TaTT MoA. On the second point, as explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *21) Subjective norms >> See 9 above*
Response: As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *22) Attitude towards the behaviour*
'mechanism of action through bodily disposition' 'Attitude' (or one of its subclasses)
'mechanism of action through bodily disposition' 'evaluative belief ' **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.
Reviewer 1: *23) Motivation*
'mechanism of action through bodily process' 'Behavioural motivation' **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *24) Self-image:*
Belief – see 9 above
Identity – see 8 above **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *25) Needs, Values*
>> as above, use with 'mechanism of action through bodily process' **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *26) Feedback processes*
'mechanism of action through bodily process' 'Social comparison process'
'mechanism of action through bodily process' 'Mentally comparing against a standard'
***please explain how you could link 'Feedback process to a person' to one of the mechanism of actions of the ontology. I'm not sure how to do it.* **Response:** We thank the reviewer for their comment, as they suggested an upper-level class was needed in the MoA Ontology to capture MoAs working through these feedback processes. This class has now been added to the ontology (“mechanism of action through feedback process to a person”). The number of classes in the MoA Ontology, reported in this manuscript, has also been updated to reflect the most recent release of the ontology.
Reviewer 1: *27) Social learning/imitation*
'mechanism of action through bodily process' 'Observational learning' **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our

mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *28) Behavioural cueing*
Stimulus is a direct child of Entity in BCIO.
***please explain how you could link it to one of the mechanism of actions of the ontology. I'm not sure how to do it.* **Response:** We thank the reviewer for their comment, as they suggested an upper-level class was needed in the MoA Ontology to capture MoAs working through stimulus. This class has now been added to the ontology ("mechanism of action through stimulus"). The number of classes in the MoA Ontology, reported in this manuscript, has also been updated to reflect the most recent release of the ontology.

Reviewer 1: *29) General attitudes/beliefs*
>> See above RE: beliefs, attitudes **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community.

Reviewer 1: *30) Perceived susceptibility/vulnerability*
>> See above RE: beliefs, attitudes **Response:** As explained above, we would like to continue using the simple approach to capture these MoAs in our mapping. We opt for this approach to enable clearer communication with members of the behavioural and social sciences community. **References** 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. *Ann Behav Med.* 2019;53(8):693–707. 30304386 10.1093/abm/kay078 6636886 Connell, L. E., Carey, R. N., De Bruin, M., Rothman, A. J., Johnston, M., Kelly, M. P., & Michie, S. (2019). Links between behavior change techniques and mechanisms of action: an expert consensus study. *Annals of behavioral medicine*, *53*(8), 708-720. Johnston M, Carey RN, Connell Bohlen L, et al.: Linking Behavior Change Techniques and Mechanisms of Action: Triangulation of findings from literature synthesis and expert consensus. *Ann Behav Med.* 2018. 10.31234/osf.io/ur6kz

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