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Improving Behavioural Interventions with Ontologies

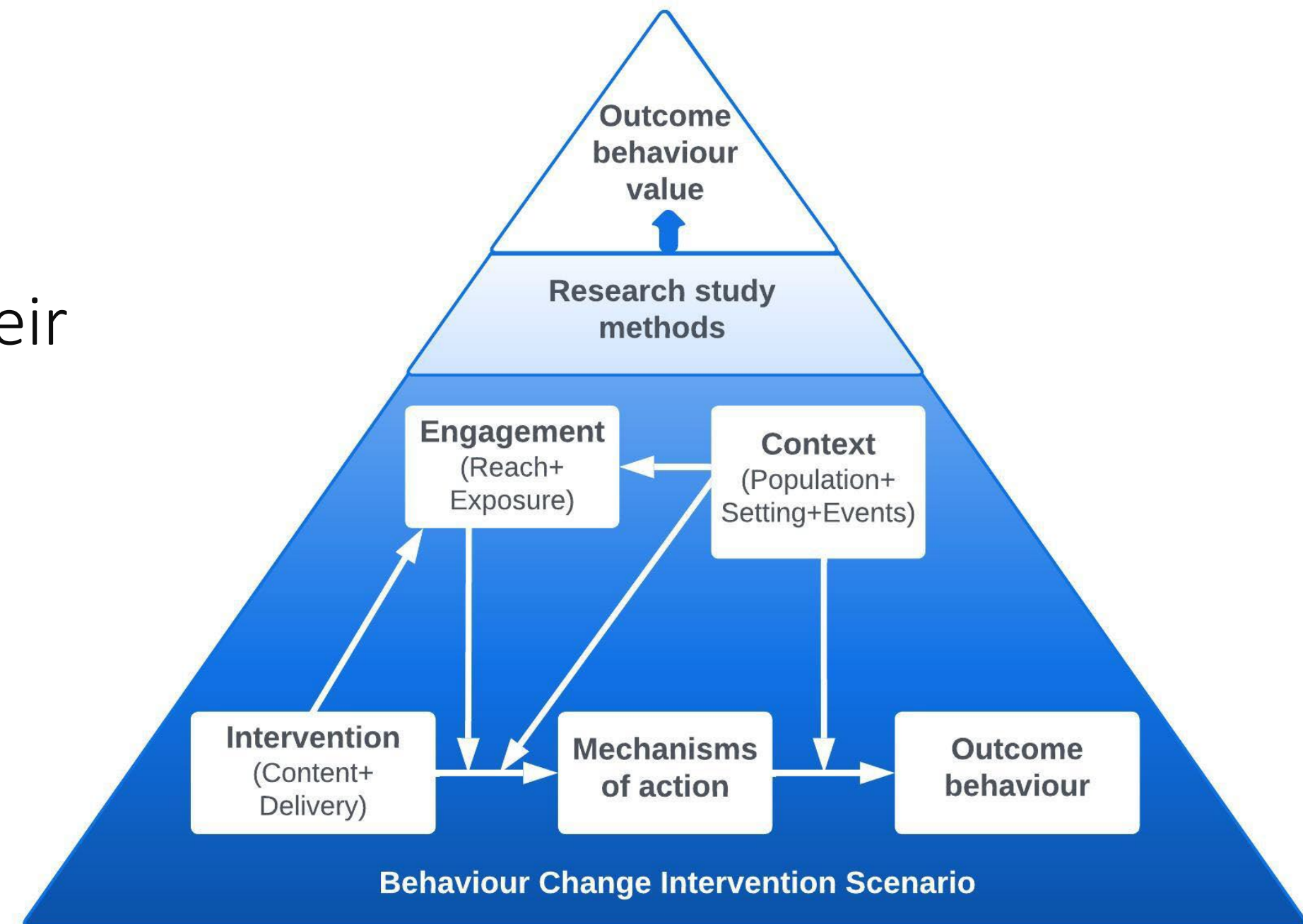
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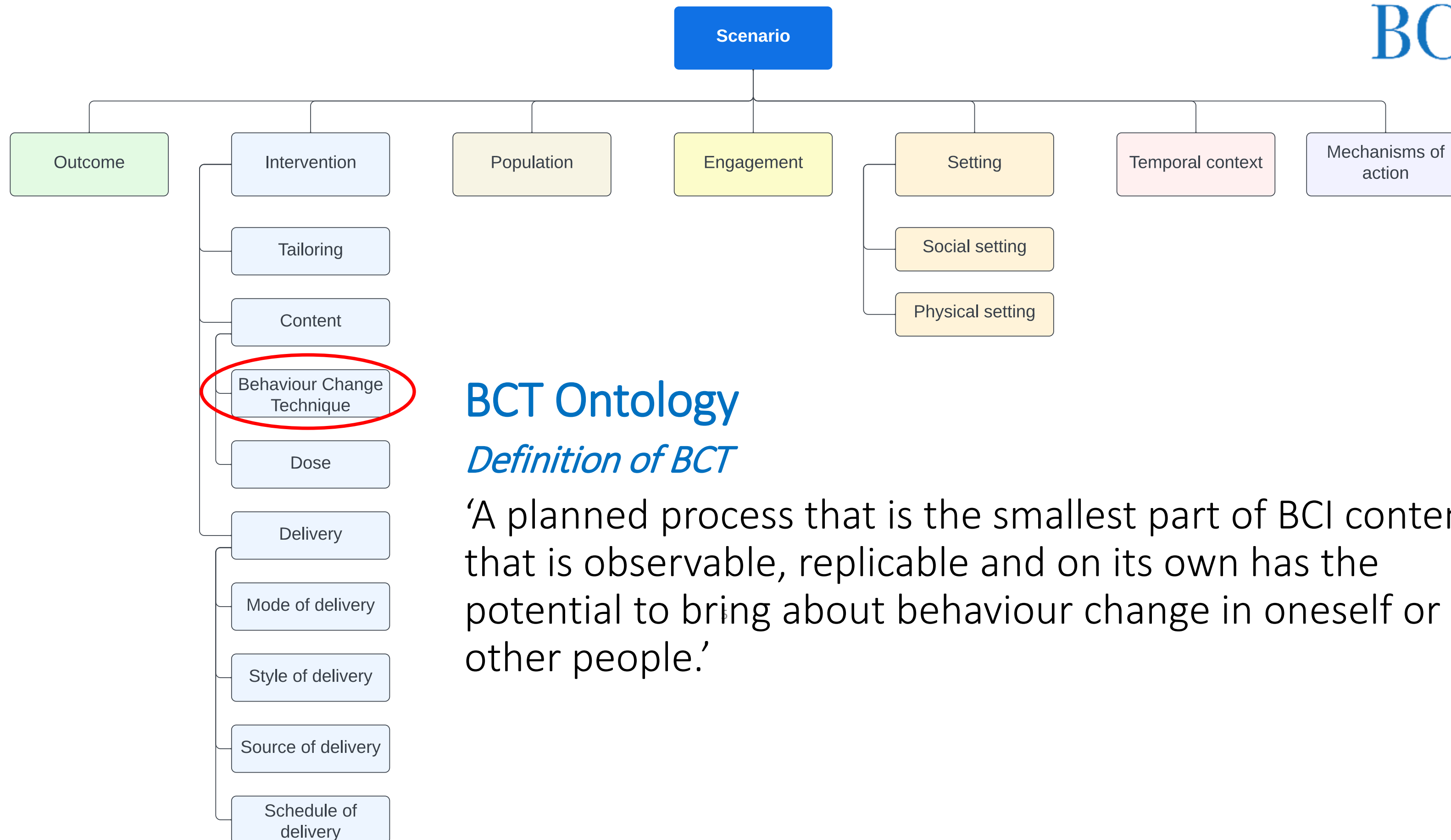
The Behaviour Change Intervention Ontology

- Characterizes all aspects of human behaviour change interventions, their contexts and their evaluations
- Unambiguous, clear and standardized classifications



Use Case: The Behaviour Change Technique (BCT) Ontology

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BCT Ontology

Definition of BCT

‘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 in oneself or other people.’

Behaviour Change Technique Taxonomy v1 (BCTTv1)

Grouping and BCTs
1. Goals and planning
1.1. Goal setting (behavior)
1.2. Problem solving
1.3. Goal setting (outcome)
1.4. Action planning
1.5. Review behavior goal(s)
1.6. Discrepancy between <u>current behavior</u> and goal
1.7. Review outcome goal(s)
1.8. Behavioral contract
1.9. Commitment

- 93 Behaviour change techniques
 - Labels, definition and examples
- 16 groups

ann. behav. med.
DOI 10.1007/s12160-013-9486-6

ORIGINAL ARTICLE

The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions

Susan Michie, DPhil, CPsychol • Michelle Richardson, PhD • Marie Johnston, PhD, CPsychol • Charles Abraham, DPhil, CPsychol • Jill Francis, PhD, CPsychol • Wendy Hardeman, PhD • Martin P. Eccles, MD • James Cane, PhD • Caroline E. Wood, PhD

<https://doi.org/10.1007/s12160-013-9486-6>



RESEARCH ARTICLE

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

Elizabeth Corker ^{1,2*}, Marta M. Marques ^{3*}, Marie Johnston ⁴, Robert West ¹, Janna Hastings ¹, Susan Michie ¹

Why develop a BCT Ontology (if we already have a Taxonomy)?

Group labels

- Undefined
- Difficult to understand

> 93 BCTs

- Missing BCTs
- Some BCTs needed to be separated into more BCTs
- Self-initiated or external

Structure

- Based on cluster analyses (not logical)
- BCTs couldn't be added

Lack of interoperability

- Link to other classifications of BCTs and BCIs

<https://doi.org/10.12688/wellcomeopenres.18002.2>

Sources used:

Feedback on BCTTv1 (2015-2021)

- BCCTv1 Online Feedback Portal
- BCCTv1 user survey
- Theories and Techniques project
- Consultation activity

Review of the Literature (2022)

- Papers, reports with classifications systems, other BCTs, etc.
- *E.g.* Compendium of self-enactable techniques (Knittle et al., 2020)

Human Behaviour-Change Project (2017-2018)

- Annotations from the literature
- Team Discussions
- Lessons from the other ontologies being developed



Analysis of 282 comments/suggestions and additional BCTs

<https://doi.org/10.12688/wellcomeopenres.18002.2>

An example of a BCT in the Taxonomy v1 and in the BCTO

3. Social support

3.1. Social support (unspecified)

3.2. Social support (practical)

3.3. Social support (emotional)



Definition of Social Support BCT in BCTO

‘A BCT that involves advising, arranging or delivering the support or aid of another person.’



Social Support BCT

- ADVISE to seek support BCT
 - Advise to seek INSTRUMENTAL support BCT
 - Advise to seek EMOTIONAL support BCT
 - Advise to seek INFORMATIONAL support BCT
 - Advise to seek APPRAISAL support BCT
- ARRANGE support BCT
 - Arrange instrumental support BCT
 - Arrange emotional support BCT
 - Arrange informational support BCT
 - Arrange appraisal support BCT
- DELIVER support BCT
 - Deliver instrumental support BCT
 - Deliver emotional support BCT
 - Deliver informational support BCT
 - Deliver appraisal support BCT

Development of the BCTO

Step 1: Extract and synthesise feedback on the BCTTv1



Step 2: Changes to BCTS: Labels and definitions



Step 3: Structuring the BCTO as an ontology



Step 4: Expert Stakeholder Feedback

326 comments via online survey



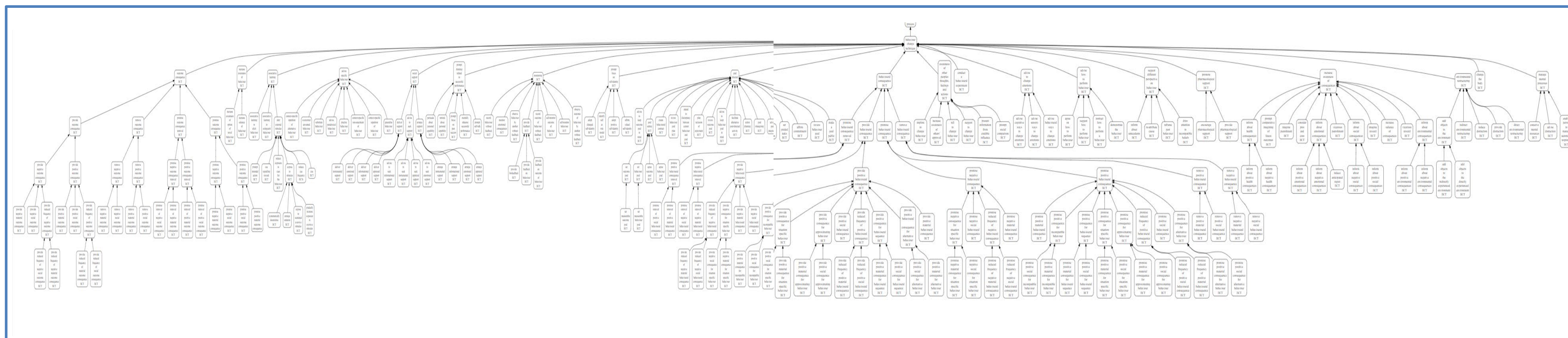
Step 5: Inter-rater reliability of annotations using the BCTO

Alpha =0.82 and 0.79

<https://doi.org/10.12688/wellcomeopenres.19363.2>

The Structure of BCTO:

- 281 BCTs organised into
- 20 higher-level groups over ...
- 5 hierarchical levels.

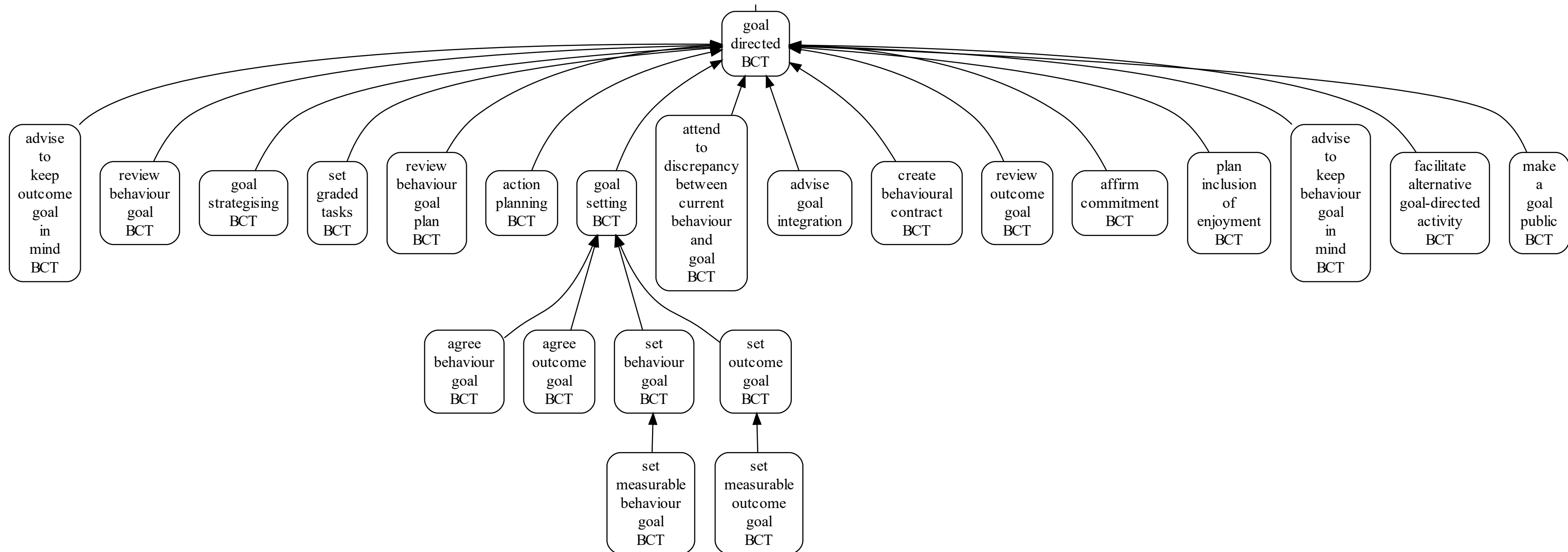


<https://bciovis.hbcptools.org/>

20 higher-level groups

BCT Group	No. of BCTs in the group	BCT Group	No. of BCTs in the group
Goal directed BCT	23	Advise specific behaviour BCT	9
Monitoring BCT	12	Manage mental processes BCT	4
Social Support BCT	16	Prompt thinking related to mental processes BCT	6
Guide how to perform behaviour BCT	6	Change the body BCT	1
Conduct a behaviour experiment BCT	1	Promote pharmacological support BCT	3
Suggest different perspective on behaviour BCT	5	Advise how to change emotions BCT	20
Increase awareness of behaviour BCT	3	Restructure the environment BCT	12
Increase awareness of consequences BCT	21	Prompt focus on self-identity BCT	5
Awareness of other people's thoughts, feelings or actions BCT	7	Behavioural consequence BCT	77
Associative learning BCT	15	Outcome consequence BCT	35

Excerpt: *Goal Directed BCT* group



<https://bciovis.hbcptools.org/visualise>

Example of Labels and Definitions

Level 1 label	Level 2 label	Level 3 label	Level 4 label	Definition
goal directed BCT BCIO:007001				A <behaviour change technique> that sets or changes goals.
	goal setting BCT BCIO:007002			A <goal directed BCT> that sets goals.
		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.
		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:007300	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.

<https://wellcomeopenresearch.org/articles/8-308>

goal setting BCT

<https://bciosearch.org/BCIO:007002>

Copy Link

Example of a BCT entry in the BCTO

ID ?	Curation status ?	Created ?	Modified ?
BCIO:007002	● Published	12 May '23	4 Jun '23

Parents ?

entity > occurrent > process > Activity > planned process > behaviour change technique > goal directed BCT > goal setting BCT

Children ?

- agree outcome goal BCT
- agree behaviour goal BCT
- set behaviour goal BCT
 - set measurable behaviour goal BCT
- set outcome goal BCT
 - set measurable outcome goal BCT

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Definition ?

A goal directed BCT that sets goals.

Examples ?

A goal is an explicit representation of a desired end state

Fuzzy set ?

No

BCIO lower level ontology ?

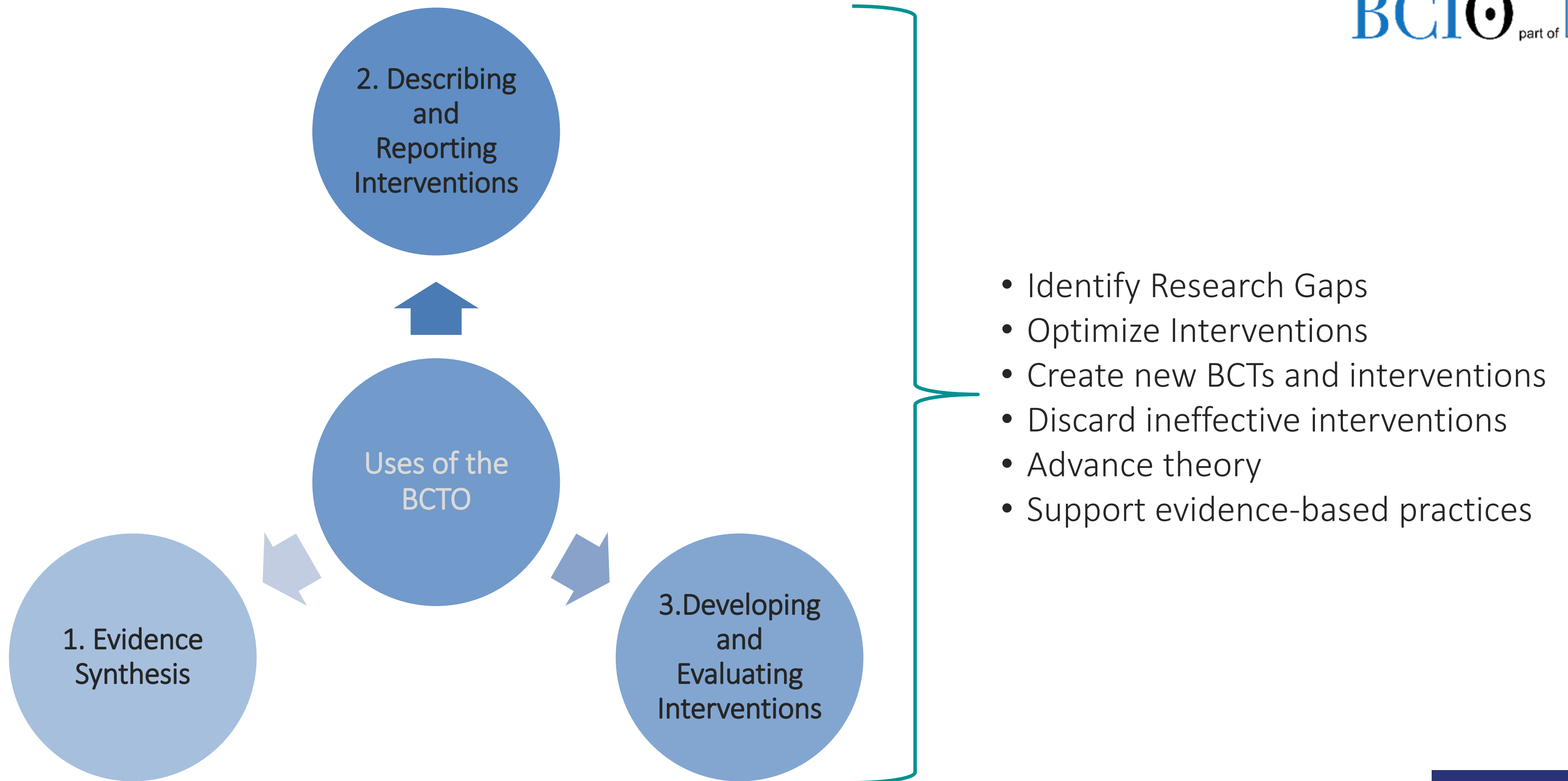
none

Mapping between BCTO and BCTTv1


BCTO label and ID	BCTO definition Note: Angled brackets (< and >) around some of the text indicate that it is the parent class	Closest BCT in BCTTv1	BCTTv1 definition
BCTO higher level group: Goal directed BCT			
goal directed BCT [BCIO:007001]	A <behaviour change technique> that sets or changes goals.	<i>New BCT</i>	
goal setting BCT [BCIO:007002]	A <goal directed BCT> that sets goals.	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome)	Set or agree on a goal defined in terms of the behaviour to be achieved Set or agree on a goal defined in terms of a positive outcome of wanted behaviour
set behaviour goal BCT [BCIO:007003]	A <goal setting BCT> that sets a goal for the behaviour to be achieved.	1.1 Goal setting (behaviour)	Set or agree on a goal defined in terms of 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.	<i>New BCT</i>	
agree behaviour goal BCT [BCIO:007004]	A <goal setting BCT> that involves the intervention source agreeing with the person on a behavioural goal.	1.1 Goal setting (behaviour)	Set or agree on a goal defined in terms of the behaviour to be achieved
set outcome goal BCT [BCIO:007005]	A <goal setting BCT> in which the goal is a positive outcome of performing the behaviour.	1.3 Goal setting (outcome)	Set or agree on a goal defined in terms of a positive outcome of wanted behaviour

How can we improve behavioural interventions using the BCTO (and BCIO)?

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1. BCTO for Evidence Synthesis and Coding/Annotation of Behavioural Interventions

- **Standardisation of terminology**
 - Defined entities
 - Not just labels
- **Systematic structure** (not arbitrary)
- **Uniform identifiers** (URIs) 
 - Potential for computer reading
- **Potential for advanced data analysis techniques**
 - e.g. Machine learning and AI
 - Identifying patterns and relationships

set behaviour goal BCT BCIO:007003	
	set measurable behaviour goal BCT BCIO:007300

Ontology-informed machine learning algorithms



Prediction

tool

part of

HB

CP

Smoking Cessation

Intervention

☐ 1.1.Goal setting (behavior)

☐ 1.2 Problem solving

☐ 1.4 Action planning

☐ 1.8 Behavioral contract

☐ 11.1 Pharmacological support

☐ 11.2 Reduce negative emotions

☐ 12.3 Avoidance/reducing exposure to cues for the behavior

☐ 12.5 Adding objects to the environment

☐ 12.6 Body changes

☐ 13.2 Framing/reframing

☐ 2.2 Feedback on behaviour

☐ 2.3 Self-monitoring of behavior

☐ 2.7 Feedback on outcome(s) of behavior

☐ 3.1 Social support (unspecified)

☐ 3.2 Social support (practical)

☐ 4.1 Instruction on how to perform the behavior

☐ 4.2 Information about Antecedents

☐ 4.5. Advise to change behavior

☐ 5.1 Information about health consequences

☐ 5.3 Information about social and environmental consequences

☐ 7.3 Reduce prompts/cues

Mean age

15

50

80

15

22

29

36

43

50

57

64

71

78

80

Mean number of times tobacco used

1

10

30

1

4

7

10

13

16

19

22

25

28

30

Outcome

☒ Abstinence: Continuous

☐ Abstinence: Point Prevalence

☐ Biochemical verification

Proportion female

0

50

100

0

10

20

30

40

50

60

70

80

90

100

Follow up (weeks)

4

26

4

10

16

22

28

34

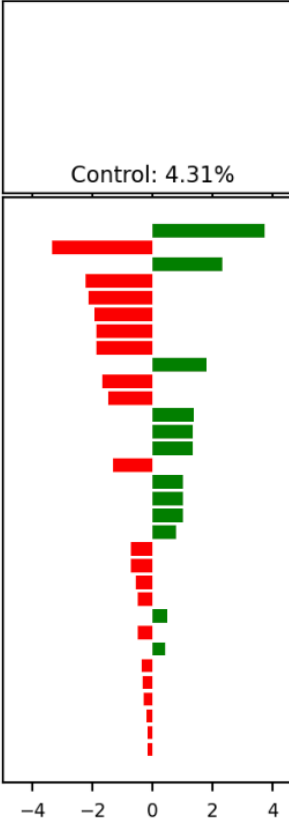
40

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☐ Patient role?

Intervention: 7.02%

Control: 4.31%



Intervention: Rules applied

Control: Rules applied

Mean number of times tobacco used (<= 10): 3.7

Abstinence: Continuous : -3.4

Combined follow up (Reported): 2.3

control: -2.2

Combined follow up (<= 20 months): -2.1

Combined follow up (<= 15 month): -1.9

Proportion identifying as male gender (<= 60): -1.9

Combined follow up (Reported) & Mean age (adult) & Proportion identifying as female gender (<= 60): -1.9

Mean age (adult): 1.8

Combined follow up (Reported) & Mean age (adult) & Mean number of times tobacco used (<= 25): -1.7

Combined follow up (Reported) & Mean age (adult) & Mean number of times tobacco used (<= 10): -1.5

Combined follow up (<= 15 month) & Proportion identifying as female gender (<= 60) & Proportion identifying as male gender (<= 99): 1.4

Combined follow up (<= 15 month) & Proportion identifying as female gender (<= 60): 1.3

Combined follow up (<= 15 month) & Proportion identifying as female gender (<= 60) & Proportion identifying as male gender (<= 99): 1.3

Combined follow up (Reported) & Mean age (adult) & Mean number of times tobacco used (<= 20): -1.3

Combined follow up (<= 28 months): 1.0

Mean number of times tobacco used (<= 25): 1.0

Mean number of times tobacco used (<= 20): 1.0

Combined follow up (Reported) & Mean age (adult) & Mean number of times tobacco used (Reported): 0.8

Combined follow up (<= 15 month) & Proportion identifying as female gender (<= 60) & Proportion identifying as male gender (<= 60): -0.7

Mean number of times tobacco used (<= 15): -0.7

Proportion identifying as female gender (<= 99): -0.5

Combined follow up (Reported) & Mean age (adult) & control: -0.5

Combined follow up (Reported) & Mean age (adult) & Proportion identifying as male gender (<= 99): 0.5

Proportion identifying as male gender (<= 99): -0.5

Combined follow up (Reported) & Mean age (adult) & Proportion identifying as female gender (<= 99): 0.4

Proportion identifying as female gender (<= 60): -0.4

Mean number of times tobacco used (Reported): -0.3

Combined follow up (Reported) & Mean age (adult) & Proportion identifying as male gender (<= 60): -0.3

<https://pred.hbcptools.org/interface/>

<https://wellcomeopenresearch.org/articles/8-503>

Using the BCTO for annotating behavioural interventions

- Annotate reports using entities in the BCTO
 - Using software such as EPPI-Reviewer or a spreadsheet
- BCTO annotation manual (<https://osf.io/mwv2c>)
 - Paper with illustrations of BCTs in the pipeline
- New BCIO template available for annotating (Norris et al, 2024; <https://osf.io/x6afp/>)
- Build a library of
 - Interventions annotated with the new template
 - Papers using the ontologies



<https://forms.gle/UkVNWqLJEjV3oyEX9>

2. Describing and reporting behavioural interventions

- Clear consistent and standardized terminology
 - Deals with different terms for the same thing or the same term for different things
- More granularity
- Comprehensive
 - Prompts - reduce omissions
- Uniform identifiers (URIs)
 - Avoid jingle-jangle
- Paper authoring tool

Group	Behavioral change technique	Application in our interventions
Goal directed	1 Set a measurable behavior goal	Anchor/goal in persuasive messages
	2 Attend to discrepancy between current behavior and goal	Feedback-goal discrepancy between continuous real-time eco-feedback and anchor/goal in persuasive messages
Monitoring	3 Record behavior without feedback	Behavioral observations in the control condition
	4 Provide feedback	Continuous real-time eco-feedback
Awareness of behavior	5 Increase salience of the behavior	Smart device installed in shower cubicles in addition to the messages
Awareness of other people's thoughts, feelings, or actions	6 Prompt social comparison	Social norm in persuasive messages compared to the continuous real-time eco-feedback
	7 Suggest a change in behavior	Gamification via persuasive messages

Pereira-Doel, P. et al., 2024) Reducing Shower Duration in Tourist Accommodations: A Covert True Experiment of Continuous Real-Time Eco-Feedback and Persuasive Messaging. <https://doi.org/10.1177/00472875241245045>

3. Developing Behavioural Interventions

- **Identify BCT(s) that can be used in a given intervention from the BCTO**
 - There is more choice and granularity than in the BCTTv1
 - One may identify new techniques that would not be considered otherwise
 - **BCTO is computer-readable**
 - Can be used when developing interventions using digital systems
 - **Crucial role in the data flow process in an intervention**
 - Organize data- standardized and classify
 - Contextualize the information
 - Support interpretation
- Support decision-making**

E.g. Lisowska et al (2023). <https://doi.org/10.1016/j.jbi.2022.104276>

3. Developing Behavioural Interventions

- **Interoperability:** Match to other components that have direct links with BCTs

Other characteristics of the content and delivery of interventions

- Dose - Amount of a BCT
- Schedule of Delivery of a BCT (e.g. frequency)
- Mode of Delivery of a BCT (e.g. face-to-face, mobile)
- Source of Delivery of a BCT (e.g. nurse)
- Style of Delivery of a BCT (e.g. emphatic communication style)
- Tailoring of a BCT (e.g. dynamic tailoring)

Interoperability

Link with Mechanisms of Action and theories

Wellcome Open Research

Wellcome Open Research 2023, 8:337 Last updated: 08 APR 2024

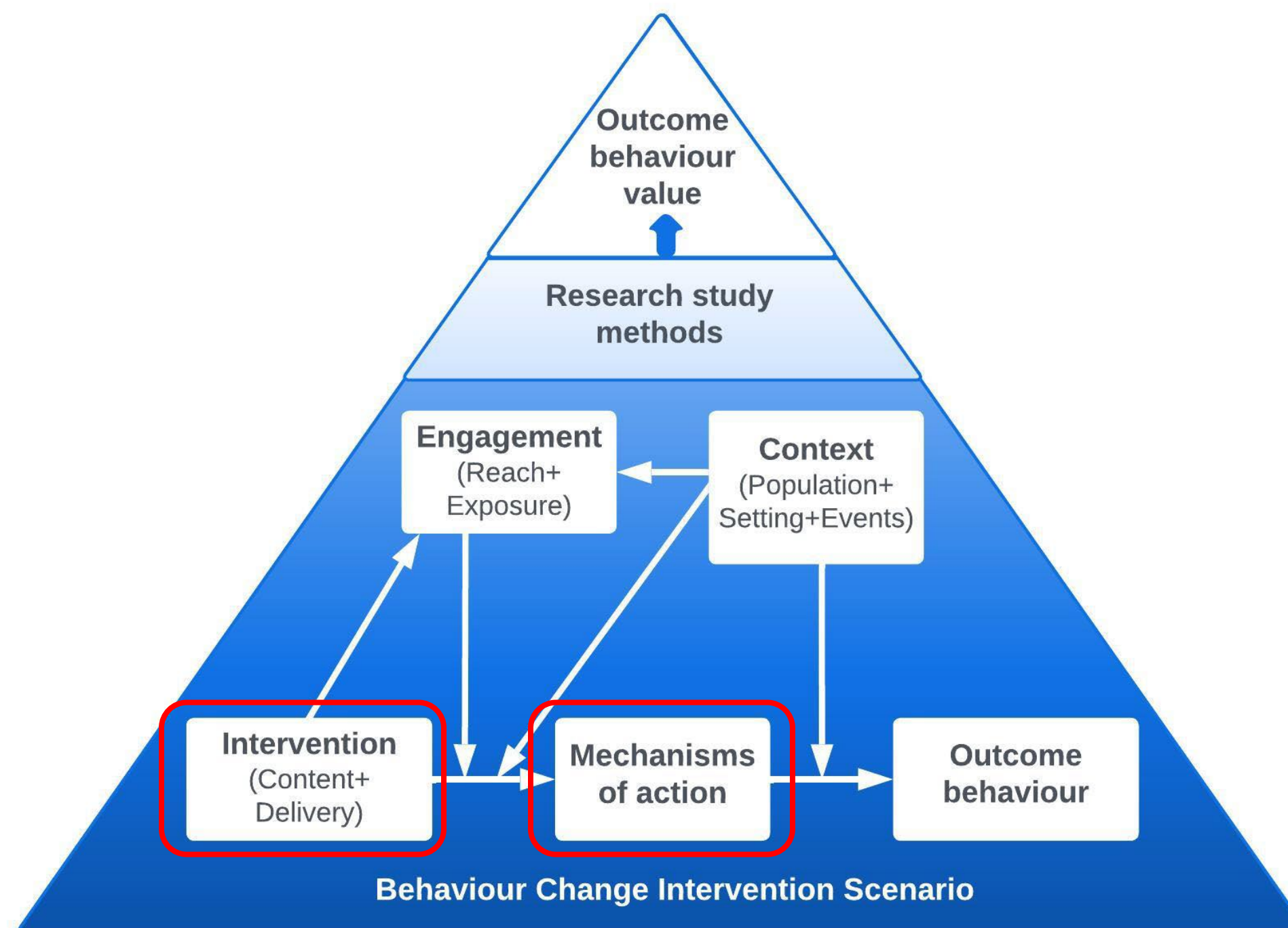


RESEARCH ARTICLE

An ontology of mechanisms of action in behaviour change

interventions [version 1; peer review: 2 approved]

Paulina M. Schenk¹, Alison J. Wright^{1,2}, Robert West³, Janna Hastings^{4,5}, Fabiana Lorencatto¹, Candice Moore¹, Emily Hayes¹, Verena Schneider⁶, Susan Michie¹



Linking BCTs with Mechanisms of Action

What is the behaviour that needs to change?

- Walking (BCIO:036108)

What MoA could be changed to change that behaviour?

- Self-efficacy belief for a behaviour (BCIO_006154)

What BCTs might change that behaviour?

- Demonstrate the behaviour BCT (BCIO:007055)
- Instruct how to perform the behaviour BCIO: 007058)

Linking BCTs with Mechanisms of Action

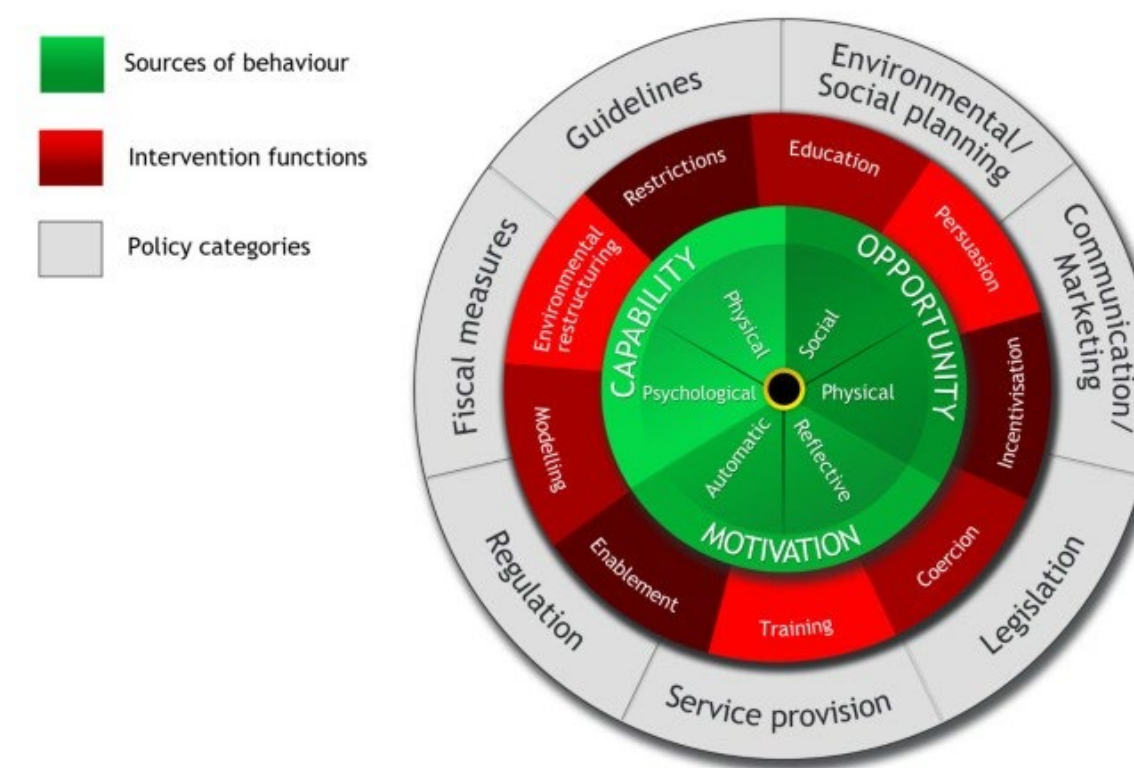
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3. Developing Behavioural Interventions

- **Combine with frameworks** that support intervention development and evaluation

E.g.

- Behaviour Change Wheel (Michie et al, 2015)
 - Soon with an ontological representation
- MOST Framework (Collins et al., 2018)





Going back to the big question:

When it comes to behaviour change interventions:

What works, compared with what,
for what behaviours,
how well, for how long, with whom,
in what setting,
and why?



- Identify Research Gaps
- Optimize Interventions
- Create new BCTs and interventions
- Discard ineffective interventions
- Advance theory
- Support evidence-based practices

Thank you

Acknowledgements:

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- All stakeholders involved