Classification systems in behavioural science: current systems and lessons from the natural, medical and social sciences

Zoe Stavri & Susan Michie

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Zoe Stavri and Susan Michie*

Department of Clinical, Educational and Health Psychology, University College London, London, UK

Background: Specifying individual behaviour change techniques (BCTs) is crucial for better development and evaluation of behaviour change interventions. Classification of BCTs will help this process and can be informed by classification systems in the natural, medical and social sciences. *Method:* A search of the classification literature in the natural, medical and social sciences produced a framework within which to consider a systematic search of classification systems of BCTs in the behaviour change literature. *Results:* Six distinct types of classification system from other scientific disciplines were identified: nomenclatures, ordered sets, hierarchical, matrices, faceted and social categorisations. Eight classification systems of BCTs were identified, none of which had a formal, hierarchical structure. Most were developed for specific behaviours, although one was general. *Discussion:* Developing a hierarchical structure, similar to those used in other scientific disciplines, would enable better communication and understanding of BCTs and inform the development and evaluation of interventions. Hierarchical structured classification systems contain many of the characteristics most desirable in a classification of BCTs.

Keywords: classification; taxonomy; behaviour change techniques; behavioural interventions; behaviour change; behaviour

Introduction

Behaviour change interventions are widely used in promoting population health, by preventing disease, managing illness and improving health care delivery. While there are many examples of successful interventions, effects are variable and many have only modest effects (NICE, 2007). Developing a science and technology of behaviour change requires replication, linking of interventions to theory (mechanisms of action) and evidence synthesis (Michie, Johnston, Francis, Hardeman, & Eccles, 2008). These would benefit from a systematic approach to specifying intervention characteristics, including their content, that is, the component techniques with the potential to bring about behaviour change. This is a starting point for assessing in what circumstances different types of intervention are likely to be effective.

While guidelines such as CONSORT (Moher, Schulz, & Altman, 2001) exist for reporting details of interventions, they do not provide a method for specifying their content. There are a multitude of behaviour change techniques (BCTs) that are delivered in a wide variety of combinations and with a wide variety of methods

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*Corresponding author. Email: s.michie@ucl.ac.uk

('modes of delivery') (see Abraham, Kelly, West, & Michie, 2009; Michie, Abraham, Whittington, McAteer, & Gupta, 2009). A BCT is a specific (i.e., distinct from other BCTs), irreducible (i.e., cannot be broken down further), component of an intervention designed to change behaviour. It is a putative active ingredient in an intervention, which can be used alone or in combination with other BCTs and its effectiveness can be assessed. For example, motivational interviewing is *not* a BCT as it is a cluster of BCTs used in combination. However, self-monitoring *is* a BCT as it is distinct from other BCTs and irreducible – although it consists of two elements (observing and recording), without either of these, it would cease to be self-monitoring.

Methods of specifying, defining and classifying BCTs have been developed; examples are Abraham and Michie's (2008) list of 26 techniques for healthy eating and physical activity, its subsequent development into 40 BCTs (Michie et al., 2011a) and Albarracín et al.'s (2005) 10 techniques for promoting condom use. These are best described as nomenclatures, lacking structure and with BCTs varying widely in scope and specificity. Attempts have been made at structuring nomenclatures of BCTs, such as a classification of BCTs for road safety, which has a tree-like structure (Geller et al., 1990), a classification of BCTs for weight management which categorised according to mode of delivery and theoretical basis of the intervention (Hardeman, Griffin, Johnston, Kinmonth, & Wareham, 2000) and a classification of BCTs for smoking cessation, which classified according to theoretical basis of the BCT (Michie, Churchill, & West, 2011). These few examples from behavioural science have different structures and do not share a method of development, nor do they draw on methods used from other scientific disciplines. Whilst this may not be a problem, behavioural science is a young science and may benefit from drawing on the experience and accumulated expertise within other, more established sciences. The need to optimise our methods becomes more acute as more investment is made in basic and applied behavioural science, multidisciplinary research is increasing and limitations are evident in current methods of synthesising evidence from studies of heterogeneous interventions to change behaviour (e.g., NICE, 2007). This article reports a structured review aimed at identifying and describing current classification systems of BCTs and evaluating them in the context of classification systems used in the natural, medical and social sciences.

Classification is the process of grouping objects according to similarity. Although the terms 'taxonomy' and 'classification system (or scheme)' are often used interchangeably, the term 'classification system' is broader. While classification systems can refer to any method of classifying or grouping items, taxonomies have tree-like structures reflecting their hierarchical nature. They are predictable and logical (Broughton, 2004) and share a methodology for development (Bailey, 1994).

In the natural, medical and social sciences, there are six types of classification system: nomenclatures, ordered sets, hierarchical, matrices, faceted and social categorisations (see Table 1).

A nomenclature is an unstructured system of terms, with classification dependent on the precise meaning of the terms. This is illustrated within astronomy where Pluto was de-classified as a planet following the International Astronomical Union (IAU) adopted a definition of 'planet' as 'a celestial body which (1) is in orbit around the Sun; (2) has sufficient mass so that it assumes hydrostatic equilibrium (i.e. it is round); (3) has cleared the neighbourhood around its orbit' (IAU, 2008, 2009). Pluto

Table 1. Characteristics of classification systems from the natural, medical and social sciences.

	Nomenclatures	Ordered set	Hierarchical	Matrix	Faceted	Social categorisation
Examples	Planets	Musical scale, Bloom's taxonomy	Linnaean taxonomy, cladistic classification; Library classifications, ICD-10	Periodic table of the chemical elements	Colon classification (library); SNOMED	Folksonomy
Purpose of classification	Necessary starting point for classification	Describe the relationship between objects in the set	Describe similarities or differences heuristically; enable quick retrieval of information	Allow systematic comparison of properties of objects	Address the shortcomings of traditional hierarchical classification, classify an object based on multiple characteristics simultaneously	Allow website users to classify content in their own schema
Hierarchical structure	No	No	Yes	No	Multiple hierarchies are possible	No
Prediction possible	No	Yes	Yes	Yes	No	No
Method of development	Consensus	Mathematical or consensus	Mathematical or consensus	Mathematical or consensus	Consensus	Consensus
Multiple classifications permitted	No	No	No	No	Yes	Yes
Basis of classification	None	Mathematical relationships, existing scientific knowledge	Similarities and differences	Existing scientific knowledge	None: pragmatic method of classification	Personal schema of website users
Ability to accommodate new discoveries	Poor: definitions may change	Poor: sets are fixed	Good	Good	Good: categories are flexible	Good

failed to meet the third criterion, as it is located in the Kuiper Belt, an icy, dusty region of the solar system. The decision was met with disagreement by the general public, who had, since its discovery, culturally defined Pluto as a planet. The IAU had indeed considered using a cultural definition of planets: an object is a planet if enough people say it is. This was rejected as not being 'meaningful' (Eales, 2007), although the meaning of 'meaningful' was not further elaborated.

An ordered set involves placing objects to be classified in a logical order, for example, ascending size. Ordered set classification systems communicate information about the relationships between the classified objects. An example is the octave used in Western music, a set of 12 evenly spaced tones in which the last tone has twice the frequency of the first. Consonance ('pleasingness') and dissonance of sound are related to mathematical relationships between the sounds. Another example is Bloom's Taxonomy (Bloom, 1956; cited in Bloom, 1994) of educational objectives which are divided into three 'domains': the cognitive, affective and psychomotor. Within each of these domains are levels, ascending from the lowest level of processing through to the highest. For example, the cognitive domain consists of levels of knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 1956; cited in Kreitzer & Madaus, 1994). The levels differ only in complexity, i.e., knowledge is necessary for comprehension to occur. Statistical tests of this assumption have produced mixed results, generally showing support for the notion of a cumulative structure (as in a hierarchy, in which lower levels contain all the characteristics of higher levels), although the order produced may be different (Kreitzer & Madaus, 1994). Investigations using cluster analysis and path analysis methods have been met with mixed success. For example, 'knowledge' does not appear to fit within the hierarchy. Likewise, path analysis suggests that the orders of 'analysis' and 'synthesis' may be reversed. Krathwohl (1994) acknowledges the taxonomy's mathematical shortcomings, namely the lack of conclusive support for the nature and order of the levels of processing, but praises it as a heuristic framework which is useful in terms of both practical application and academic value. While it may lack the predictive abilities of other classification systems, it is a helpful practical tool for defining and classifying educational objectives and aiding examination design.

Hierarchical classification involves organising objects into groups based on similarity, using superordinate and subordinate categories. A hierarchy must meet four criteria: inclusiveness (the top category must include all below it), relational consistency (the kind of relationship between each level of the hierarchy is the same), inheritance (subordinate categories 'inherit' all of the attributes of the superordinate categories) and mutual exclusivity (an entity can belong in only one place within the hierarchy) (Lambe, 2007). While simple lists have their value, when classifying a large amount of objects, it is desirable to undertake data reduction by grouping items together. A hierarchical taxonomy enables quick retrieval of relevant information and communicates a large amount of descriptive information economically.

The most famous example of a hierarchical classification is Linnaeus's biological classification system (Linnaeus, 1751), which uses the taxonomic ranks of Kingdom, Phylum, Class, Order, Family, Genus and Species to categorise animals and plants. Each level of the taxonomy reflects a greater degree of specificity; for example, at the Kingdom level, objects are classified as animals or plants. Each has subcategories,

which are further divided into subcategories, ending with the Species level, which is the greatest level of specificity, the object itself.

In Linnaeus's time, groups were clustered subjectively. Later scientific developments led to the application of mathematical methods, known as 'numerical taxonomy'. It has its roots in the biometric movement at the beginning of the twentieth century, when statistical methods for analysing 'distance' between categories were first developed (Sneath & Sokal, 1973). 'Distance' refers to objects that are highly different on a number of dimensions, while 'similarity' refers to those which are 'closer'. The method used is typically cluster analysis, in which groups are formed by assessing similarity of objects on as many dimensions as possible, and then linking the most similar objects together into groups. By the 1960s, this had become popular, and today all biological classification systems use statistical analysis (Sneath & Sokal, 1973) known as numerical taxonomy. Numerical taxonomy has a clearly specified methodology, with the aim of logical consistency and explicit rules for dealing with problems such as overlapping clusters (Jardine & Sibson, 1971).

An alternative hierarchical classification to that based on similarities and differences has been developed to reflect new scientific knowledge following the theory of evolution which changed the conceptualisation of animals and plants from static entities to entities which have changed over millions of years (Simpson, 1961). This evolutionary approach involves classifying biological entities by 'clades', which represent *all* their common ancestry. Advocates of 'cladistics' argue that evolutionary descent and common ancestry are the most important factors in classifying biological entities and that the ranks used in traditional Linnaean taxonomy are arbitrary and restrictive (Cantino, 2000).

Technology has played an important role in helping to classify entities. For example, DNA sequencing provides an alternative to the search for physical, visible similarities between species and DNA bar coding can verify that entities are separate species (Seberg & Petersen, 2007). Furthermore, the cladistic approach is more flexible in accommodating new discoveries, as there is an inherent assumption that the shape of the 'tree' will change with more information (Hennig, 1975). Evolutionary classification allows predictions to be made: it can identify a missing ancestor of a living species and can give information about what a missing fossil would look like (Simpson, 1961).

Examples of hierarchical classification systems in other disciplines are library and medical classifications. The Library of Congress Classification and the Dewey Decimal Classification (Broughton, 2004) are not statistically based, but are rooted in logical theory and represent consensually accepted pragmatic schemes (Richmond, 1965; cited in Painter, 1972). The World Health Organisation's International Classification of Diseases (ICD-10) is organised into 22 heterogeneous higher-order categories, 'chapters'. Some refer to parts of the body (e.g., 'diseases of the nervous system'), others to mode of infection (e.g.,'certain infectious and parasitic diseases') and others, for example 'risk factors' do not refer to diseases *per se*. Items within chapters are also diverse (MacMahon & Trichopoulos, 1996). Despite this, ICD-10 codes are very useful to doctors, having been built using consensus processes and reviewed at international conferences to ensure a usable classification system (World Health Organisation, 2008).

Matrix classification involves classifying objects according to two dimensions and tabulating the results, the Periodic Table of the chemical elements being the most

famous example developed in 1869 by Russian chemist Dmitri Mendeleev. Taking a top-down approach, the Periodic Table uses atomic weight and chemical similarities to place chemical elements into a grid. This classification was based on the scientific theory of its time, the 'law of octaves', which stated that if one ordered the elements in descending order of atomic weight, the properties of the eighth element resembled that of the first (Puddephatt & Monaghan, 1986). At the time of its development, there were 'gaps' in the Table. Using the Table, Mendeleev was able to accurately predict the properties of scandium, germanium and gallium before their discovery (Bensaude-Vincent & Stengers, 1996), illustrating the value of matrix classification systems for predicting the properties of missing values.

Faceted classification classifies objects according to a number of unrelated dimensions or 'facets'. An example is The Systemised Nomenclature of Medicine (SNOMED) which was developed using consensus methods and classifies concepts related to health according to a range of characteristics including clinical findings, body structures and social context (International Health Terminology Standards Development Organisation, 2008). Faceted classification may have found its niche with the advent of the Internet; it has become a useful tool for websites where users can search for items based on facets such as price, size, type, make and so on (Lambe, 2007).

Social categorisation takes a bottom-up approach to assign keywords to content, from which groupings arise, with users constructing the classification system. This has flourished with the age of the Internet and the 'Web 2.0' movement towards user-generated content. 'Folksonomies' or 'tagsonomies' (Lambe, 2007) are created by users uploading photographs or blog posts and 'tagging' content using publicly-viewable keywords (Mathes, 2004). Consensus on tagging items has been found to conform closely to official guidelines for constructing controlled vocabularies: the tags are often nouns and tend to avoid jargon, similar to public library catalogues (Spiteri, 2007). Since user-tagging appears to produce classification systems similar to a library catalogue, it may prove to be an effective way of organising and categorising. However, they are not objectively constructed, since user tags reflect personal opinion (Peterson, 2006). Folksonomies are sets of categories or nomen-clatures rather than taxonomies as, although the labels are clear and well defined, the structure is 'flat' or non-hierarchical and does not describe relationships between categories (Mathes, 2004).

The current structured review seeks to identify and describe current classification systems of BCTs and evaluate them in the context of classification systems used in the natural, medical and social sciences.

Method

The electronic databases PsychINFO, MEDLINE and EMBASE were searched with terms 'classification' OR 'taxonomy' AND 'behavio* change' OR 'behavio* intervention' OR 'behavio* change intervention' in October 2009. These broad search terms were used to identify as many relevant classification systems as possible. References cited by the identified articles were searched. There was no limit on date of publication. Classification systems of constructs other than BCTs were excluded, as were commentaries and non-English publications. No relevant dissertations were identified.

Information about the purpose of the classification system, the number of BCTs, the structure of the classification system, definitions of the BCTs, reliability and the use of psychological theory was extracted and classification systems were compared on these dimensions. Data extraction was conducted by Zoe Stavri, and checked by Susan Michie.

Results

Inclusion and exclusion of articles is summarised in Figure 1. Of 276 articles identified, 60 were duplicates, 176 articles did not present a classification system, 28 presented classification systems, though not of BCTs, and five were commentaries. An example of an article which did not present a classification system would be one which tested a model of behaviour and classified intervention participants according to stage of change using the Transtheoretical Model (Prochaska & Velicer, 1997). An example of an article presenting a classification system, though not of BCTs, would be one which classified behaviours, or one which classified general types of intervention without elaborating specific BCTs.

This left seven articles that met the inclusion criteria (Abraham & Michie, 2008; Dywer, Leeming, Cobern, & Porter, 1993; Geller et al., 1990; Hardeman, Griffin, Johnston, Kinmonth, & Wareham, 2000; Leeman, Baernholdt, & Sandelowski, 2007; McLean, Griffin, Toney, & Hardeman, 2003; Michie, Johnston, Hardeman, Francis, & Eccles, 2008). Two additional articles (Albarracín et al., 2005; Webb & Sheeran, 2006) were located by searching the references of these articles and a further two (Embry & Biglan, 2008; Michie et al., 2011b) were identified following consultation with experts in behaviour change, giving a total of 11 classification systems. Eight are summarised in Table 2. Dwyer et al. (1993), McLean et al. (2003) and Webb and Sheeran (2006) are omitted as they constitute applications of classification systems already included in this review.
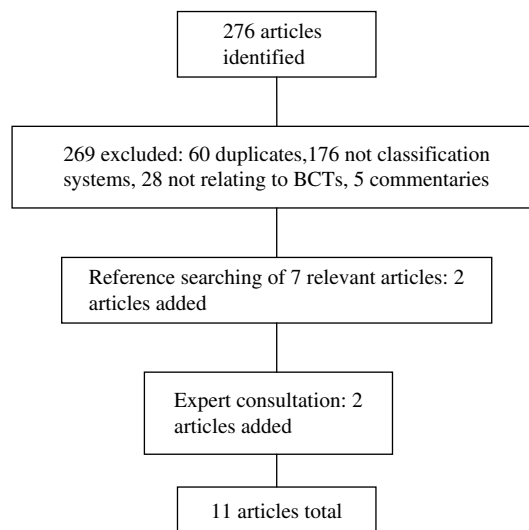

Figure 1. Inclusion of classification systems of BCTs.

Table 2. Characteristics of classification systems of BCTs.

Authors	Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011b)
Behaviour	Injury control	Prevention of weight gain	Healthy eating and physical activity	HIV prevention	Implementing change in healthcare practice	General 'behavioural influence'		Smoking cessation
Definition of a BCT	Intervention strategies	Behaviour change methods	Intervention content	'Intervention strategies that can be expected to change behaviour'	Methods for change, targeted at care providers	'Indivisible procedure shown through experimental evaluation to produce reliable effects on behaviour'; 'active ingredients' in prevention or behaviour change programs.		'Systematic procedures designed to change behaviour'
Reason for development	Heuristic framework for categorising and evaluating BCTs.	Characterise intervention methods	Develop a standardised vocabulary of intervention components, identify BCTs associated with intervention effectiveness, facilitate meta-analytical theory testing, improve fidelity of intervention replications and applications	Compare different intervention strategies	Aid reporting of what is done; provide a framework to guide selection and use of BCTs	Provide a nomenclature of BCTs		Identify competences necessary for delivering individual and group behavioural support for smoking cessation

Table 2 (*Continued*)

Authors	Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011b)
Characteristics used for classification	Techniques	Techniques, underlying model, modes of delivery (further divided into group, materials and expert behaviour change)	Techniques	Techniques, participant characteristics (ethnic descent and sexual orientation), setting	Techniques	Techniques		Techniques
Structure	2 levels	None	None	1 level	1 level	1 level	None	1 level
Reliability	–	–	85–100% agreement	Kappa 0.9–1	90% agreement	–	–	90% agreement
Theoretical basis/links	Based on antecedent-behaviour-consequence model	Classifies underlying model as well as BCTs used	Theory linked to mechanisms of behaviour which BCTs target	Items drawn from theories of behaviour change		Techniques grouped by mechanism of action. Mix of theories.		Functions of the BCTs used for groups
Method of development	Review of the behavioural science literature, particularly applied behaviour analysis.	Consultation of textbooks and experts in the field.	Inductive generation by authors from journal descriptions of interventions.	Techniques implied by health behaviour change theories were selected and organised into passive and active strategies.	Modification of an existing taxonomy, with the addition of theory.	Series of meetings of scientific and policy experts		BCTs identified from stop smoking service manuals.

Table 2 (*Continued*)

Authors	Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011b)
BCT categories and numbers	Communication/ education: n = 6 Activators: n = 12 Consequences: n = 6	$n = 19$	$n = 40$	Passive strategies: $n = 5$ Active strategies: $n = 5$	Increase coordination to manage interdependence (Contingency Theory): $n = 4$ Raise awareness of practice change (Diffusion of Innovations): $n = 2$ Persuade via interpersonal channels/norms (Diffusion of Innovations/ Theory of Planned Behaviour): n = 3 Persuade by reinforcing belief that behaviour will lead to desirable results (TPB): $n = 3$ Increase behavioural control (TPB): $n = 3$	Kernels altering consequences of behaviour: $n = 27$ Kernels affecting behaviours primarily via antecedents: $n = 8$ Kernels affecting behaviours primarily via relational frames: $n = 6$ Kernels affecting behaviours primarily via physiology: $n = 9$		Addressing motivation: $n = 12$ Maximising self-regulatory capacity: $n = 14$ Adjuvant activities: $n = 5$ General aspects of the interaction: $n = 22$

Purpose of the classification systems

All of the classification systems were developed for the purpose of systematically reviewing behaviour change interventions, covering a diverse range of behaviours. Geller et al.'s classification, developed for injury control and road safety, has been applied to environmental protection behaviours (Dwyer et al., 1993). Hardeman et al.'s (2000) classification was used for prevention of weight gain, and has been applied to weight loss interventions (McLean et al., 2003). Abraham and Michie's (2008) classification was developed to review diet and physical activity interventions. Albarracin et al.'s (2005) classification was developed for HIV prevention interventions, specifically condom use. Leeman et al.'s (2007) classification was of interventions targeting health care workers. Michie et al.'s (2008) classification was not restricted to specific behaviours and included any technique that could change behaviour. Webb and Sheeran (2006) applied Hardeman et al.'s (2000) classification to investigate the extent to which changing behavioural intention led to behaviour change.

Definitions of BCTs

Abraham and Michie (2008), Embry and Biglan (2008) and Geller et al. (1990) give definitions of BCTs, Michie et al. (2008) give definitions of some, but not all of the BCTs and Albarracin et al. (2005) give examples of how the BCTs may be applied. The remaining classification systems do not present BCT definitions.

Number of BCTs

There is considerable variation amongst the classification systems in the number of BCTs included, ranging from 19 to 137, reflecting heterogeneity in their specificity and scope (see Table 2 and Supplementary table). The smaller classification systems are targeted towards specific behaviours while the larger ones are general. The 40-item extension of Abraham and Michie's (2008) system has increased its level of specificity: for example, 'provide contingent rewards' has been broken down into 'provide rewards contingent on successful behaviour' and 'provide rewards contingent on effort or progress towards the behaviour'. It has also improved the clarity of technique labels and definitions. The 40-item version is therefore presented in Table 2 as it represents the most up-to-date version of this classification system. The largest, Michie et al.'s (2008) classification, has 137 BCTs reflecting its broad basis, drawing from textbooks relating to behaviour change and 'brainstorming' by researchers and clinicians from clinical, health and social psychology.

Structure

Four classifications have one level of hierarchy. Two of these are not true hierarchies, since they do not demonstrate relational consistency, where the kind of relationship between each level of the hierarchy is the same (Lambe, 2007). These are Albarracin et al.'s 'passive' vs 'active' groups and Leeman et al.'s five categories (increase co-ordination to manage interdependence, raise awareness of practice change, persuade via interpersonal channels/norms, persuade by reinforcing belief that behaviour will

lead to desirable results and increase behavioural control). Michie et al.'s (2011b) structure has four categories (address motivation, maximise self-regulatory capacity, promote adjuvant activities and general aspects of the interaction), as does Embry and Biglan's: altering consequences of behaviour, affecting behaviour primarily via antecedents, affecting behaviour primarily via relational frames and affecting behaviour primarily via physiology. Geller et al. (1990) has a two-level hierarchy with three higher-order categories: communication/education interventions, activators and consequences. Both communication/education and activators are said to occur before the behaviour, as preventive techniques, while consequences occur after. Confusingly, in describing the categories, both communication/education and activators are described as 'activators'. These each have two subordinate categories: communication/education is divided into active or passive interventions, while activators and consequences are both divided into individual or group interventions (see Table 2).

Faceted classification was applied by two of these classification systems to behaviour change *interventions* as opposed to the component BCTs (Albarracin et al., 2005; Hardeman et al., 2000). This allows classification of additional information such as the mode of delivery and the context in which the BCT is implemented and can facilitate the systematic investigation of interactions between different intervention characteristics.

Use of psychological theory

All classification systems use theory to some degree. Geller et al. (1990) based their classification on the antecedent-behaviour-consequence model. Hardeman et al. (2000) did not explicitly link their BCTs to theory, but classified underlying theory of the *interventions* from which the BCTs were derived. Albarracín et al. (2005) identified BCTs implied by theories of behaviour change. Abraham and Michie (2008) proposed theoretical links to each of the BCTs: for example, BCTs designed to change attitude could be linked to the Theory of Reasoned Action (Ajzen & Fishbein, 1980), the Theory of Planned Behaviour (Ajzen, 1991), Social Cognitive Theory (Bandura, 1989) or the Information-Motivation-Behavioural-Skills model. Leeman et al. (2007) linked their superordinate categories with theoretical determinants. However, in all cases, the methodology used to link BCTs to theory was unclear.

Michie et al. (2008) developed a consensus method for linking theory to BCTs. Drawing on previous work (Michie et al., 2008), they piloted a method involving a multidisciplinary group of four raters independently rating their confidence that specific BCTs could be used to change theoretical determinants of behaviour. Although they achieved 71% agreement in this exercise, this requires further work with a larger sample.

In summary, this review identified nine classification systems of BCTs, developed for a range of behaviours and mainly in relation to systematic reviewing. Five were unstructured, three had one level of grouping and one had two levels. Links to theory, or mechanisms of action, were suggestive rather than grounded in a robust methodology.

Discussion

In the natural, medical and social sciences, six distinct types of classification system are apparent: nomenclatures, ordered sets, hierarchical, matrices, faceted and social categorisations. It is evident that different systems have been developed for different purposes. Within behavioural science, eight classification systems of BCTs were identified, all either nomenclatures or simple hierarchical systems. It should be noted that our literature search was confined to articles that presented as a classification system of BCTs; a wider search of the behaviour change literature may have uncovered others.

An ideal classification system of BCTs would have clear definitions of BCTs, and be an effective tool for communicating information, for evidence synthesis and for intervention development and evaluation. One evident benefit of current classification systems of BCTs has been to advance methods of evidence synthesis to enable the identification of active ingredients where conventional meta-analyses of the data would not have succeeded (e.g., Albarracin et al., 2005; Dombrowski, Sniehotta, Avenell, MacLennon, & Araújo-Soares, 2012; Michie et al., 2009). Reviewing the classification systems developed in the natural and social sciences suggests that the hierarchical structure is the most useful for organising the increasingly long lists of BCTs being developed within Health Psychology. Efforts have begun to be made to group BCTs according to active ingredients, mechanism of action and operational use (see www.ucl.ac.uk/health-psychology/BCTtaxonomy). Groupings such as these could help systematic reviewers in categorising interventions, intervention designers in considering how BCTs may work together, evaluators in planning meta-analyses and process evaluation researchers and theorists in testing theory.

Analysing interventions by BCTs has facilitated the identification of effective components within behavioural interventions by using a statistical technique called meta-regression (e.g., Dombrowski et al., 2012; Michie et al., 2009; Webb, Joseph, Yardley, & Michie, 2010). As the existing, nomenclature-style classification systems of BCTs typically contain a large number of BCTs, many statistical tests are undertaken which increases the possibility of a Type I error. Grouping BCTs would alleviate this problem, reducing the number of tests needed to be undertaken and allow theoretically coherent groupings to be tested directly as was done by Michie et al., (2009).

An important quality of a classification system is clear definitions: precise, consensually-agreed terms are necessary for accurate reporting of interventions, thus enabling the establishment of what works and why (Michie, Fixsen, Grimshaw, & Eccles, 2009). Some classifications of BCTs have achieved this, although others present the BCTs without definitions. Embry and Biglan (2008) provided the clearest definition of a BCT, a technique that is indivisible, reliably affects behaviour and has an evidence base. Indivisibility is comparable to elements in the Periodic Table: they cannot be broken down any further, and can be used in combination. This work has been taken forward by a multidisciplinary research project, advised by an international board of 30 experts, that has produced the most comprehensive definition to date (see www.ucl.ac.uk/health-psychology/BCTtaxonomy; Michie et al., 2011a). According to this definition, BCTs (1) aim to change behaviour, (2) are proposed 'active ingredients' of interventions, (3) are the smallest components compatible with retaining the proposed active ingredients, (4) can be used alone or in

combination with other BCTs, (5) are observable and replicable, (6) can have a measurable effect on a specified behaviour[s] and (7) may or may not have an established empirical evidence base. It should be noted that many BCTs included within the current taxonomies do not conform to this definition but, rather, are compounds of BCTs. Such compounds could form a super-ordinate level in a hierarchical structure.

In theory, hierarchical classification of BCTs could take a bottom-up approach, building groups of similar techniques or a top-down approach, starting with a criterion for classification, such as similarity of theoretical basis or practical application. At present, all of the BCT classification systems with structure have taken the former approach.

Faceted classification, an alternative multidimensional classification system, cannot communicate information about relationships between items and their characteristics; a faceted classification system is essentially a set of discrete nomenclatures. Classification of relationships can be achieved with a matrix approach, but this can only support two or three characteristics, since a greater number of characteristics would render tabulating the classification system impractical. Ordered sets would be inappropriate for classifying BCTs since BCTs differ on a number of dimensions, do not build on one another and are not a fixed set.

Multidimensional classification of BCTs will help optimisation approaches to intervention development. An example of this is the multiphase optimisation strategy ('MOST'; Collins, Murphy, Nair, & Strecher, 2005) involving three phases: a screening phase, which entails selecting intervention components which merit further investigation; a refining phase, where interactions between components are investigated and optimal dosage levels are identified; and a confirming phase, in which the optimised intervention is tested. In a fractional factorial design, the number of cells required is reduced by 'aliasing' effects which are known to interact and only focusing on interactions of interest.

For hierarchical classification of BCTs, there is a question as to whether to use an evolutionary approach or base classification on similarities and differences. BCTs themselves may not evolve, *per se*, but it is likely that underpinning theories will develop as the science of behaviour change advances. It may therefore be possible to trace this evolution and link BCTs to theory to provide a classification system. One complexity is that BCTs can be linked to more than one theory: for example, Abraham and Michie (2008) suggested that the BCT, 'prompt intention formation' was linked to four different theories. This differs from classification in the natural sciences, such as that based on the evolution of animals.

On the other hand, since BCTs may be quantitatively or qualitatively similar to one another, a similarities-based ('Linnaean') may be practically more useful. The extent to which each of these methods are useful in behavioural scientific and technological development is an empirical question, awaiting further research. An international collaboration of behavioural researchers from a range of disciplines has begun a systematic development of an integrated taxonomy of BCTs and investigation of how best to structure a hierarchical classification (Michie et al., 2011a; www.ucl.ac.uk/health-psychology/BCTtaxonomy).

Conclusions

The development of more useful classification systems in behavioural science can be informed by existing classification systems in the natural, medical and social sciences. The simplest classification systems, nomenclatures, start with clear definitions of what is to be classified. More complex classification systems offer an opportunity to examine relationships between what is classified. Classifications of BCTs vary in their structures, use of theory and how a BCT is defined; advantages of a hierarchical structure are presented. Drawing on the knowledge of classification systems across science will help achieve the aim of developing a fully fit for purpose taxonomy of BCTs, a valuable tool for developing and evaluating behaviour change interventions.

References

Abraham, C., Kelly, M.P., West, R., & Michie, S. (2009). The UK national institute for health and clinical excellence public health guidance on behaviour change: A brief introduction. *Psychology, Health and Medicine*, *14*, 1–8.

Abraham, C., & Michie, S. (2008). A taxonomy of behaviour change techniques used in interventions. *Health Psychology*, *27*, 379–387.

Ajzen, I. (1991). The theory of planned behaviour. *Organizational Behavior and Human Decision Processes*, *50*, 179–211.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. New Jersey: Prentice-Hall.

Albarracín, D., Gillette, J.C., Earl, A.N., Glasman, L.R., Durantini, M.R., & Ho, M. (2005). A test of major assumptions about behaviour change: A comprehensive look at the effects of passive and active HIV-prevention interventions since the beginning of the epidemic. *Psychological Bulletin*, *131*, 856–897.

Bailey, K.D. (1994). *Typologies and taxonomies: An introduction to classification techniques*. London: Sage.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist*, *44*, 1175–1184.

Bensaude-Vincent, B., & Stengers, I. (1996). *A history of chemistry*. Massachusetts: Harvard University Press.

Bloom, B.S. (1994). Reflections on the development and use of the taxonomy. In L.W. Anderson & L.A. Sosniak (Eds.), *Bloom's taxonomy: A forty-year retrospective* (pp. 1–8). Chicago: University of Chicago Press.

Broughton, V. (2004). *Essential classification*. London: Facet.

Cantino, P.D. (2000). Phylogenetic nomenclature: Addressing some concerns. *Taxon*, *49*, 85–93.

Dombrowski, S.U., Sniehotta, F.F., Avenell, A., MacLennon, G., & Araújo-Soares, V. (2012). Identifying active ingredients in complex behavioural interventions for obese adults with obesity-related co-morbidities or additional risk factors for co-morbidities: A systematic review. *Health Psychology Review*, *6*, 1–25.

Dwyer, W.O., Leeming, F.C., Cobern, M.K., & Porter, B.E. (1993). Critical review of behavioural interventions to preserve the environment: Research since 1980. *Environment and Behavior*, *25*, 275–321.

Eales, S. (2007). The fallen planet. *Prospect*, *134*, 31–34.

Embry, D.D., & Biglan, A. (2008). Evidence-based kernels: Fundamental units of behavioural influence. *Clinical Child and Family Psychology Review*, *11*, 75–113.

Geller, E.S., Berry, T.D., Ludwig, T.D., Evans, R.E., Gilmore, M.R., & Clarke, S.W. (1990). A conceptual framework for developing and evaluating behaviour change interventions for injury control. *Health Education Research: Theory & Practice*, *5*, 125–137.

Hardeman, W., Griffin, S., Johnston, M., Kinmonth, A.L., & Wareham, N.J. (2000). Interventions to prevent weight gain: A systematic review of psychological models and behaviour change methods. *International Journal of Obesity*, *24*, 131–143.

Hennig, W. (1975). Cladistic analysis or cladistic classification? A reply to Ernst Mayr. *Systematic Zoology*, *24*, 244–256.

International Astronomical Union (IAU). (2008). *Resolution B5: Definition of planet in the Solar System*. Retrieved from: http://www.iau.org/static/resolutions/Resolution_GA26-5-6.pdf

International Astronomical Union (IAU). (2009). *Naming astronomical objects*. Retrieved from: http://www.iau.org/public_press/themes/naming/

International Health Terminology Standards Development Organisation. (2008). *SNOMED CT Hierarchies*. Retrieved from: http://www.ihtsdo.org/snomed-ct/snomed-ct0/snomed-ct-hierarchies/

Jardine, N., & Sibson, R. (1971). *Mathematical taxonomy*. London: John Wiley and Sons.

Krathwohl, D.R. (1994). Reflections on the taxonomy: its past, present and future. In L. W. Anderson & L. A. Sosniak (Eds.), *Bloom's Taxonomy: A Forty-Year Retrospective* (pp. 64–80). Chicago, IL: University of Chicago Press.

Kreitzer, A.E., & Madaus, G.F. (1994). Empirical investigations of the hierarchical structure of the Taxonomy. In L.W. Anderson & L.A. Sosniak (Eds.), *Bloom's taxonomy: A forty-year retrospective* (pp. 64–80). Chicago: University of Chicago Press.

Lambe, P. (2007). *Organising knowledge: Taxonomies, knowledge and organisational effectiveness*. Oxford: Chandos.

Leeman, J., Baernholdt, M., & Sandelowski, M. (2007). Developing a theory-based taxonomy of methods for implementing change in practice. *Journal of Advanced Nursing*, *58*, 191–200.

Linnaeus, C. (1751). *Philosophia Botanica* (S. Freer, Trans.). Oxford: Oxford University Press.

MacMahon, B., & Trichopoulos, D. (1996). *Epidemiology: Principles and methods* (2nd ed). Boston: Little, Brown.

Mathes, A. (2004). Folksonomies: Cooperative classificiation and communication through shared metadata. Retrieved from: http://adammathes.com/academic/computer-mediated-communication/folksonomies.pdf

McLean, N., Griffin, S., Toney, K., & Hardeman, W. (2003). Family involvement in weight control, weight maintenance and weight-loss interventions: A systematic review of randomised trials. *International Journal of Obesity*, *27*, 987–1005.

Michie, S., Hardeman, W., Fanshawe, T., Prevost, AT., Taylor, L., & Kinmonth, AL. (2008). Investigating Theoretical Explanations for Behaviour Change: The Case Study of ProActive. *Psychology and Health*, *23*, 25–39.

Michie, S., Abraham, C., Eccles, M.P., Francis, J.J., Hardeman, W., & Johnston, M. (2011). Methods for strengthening evaluation and implementation: Specifying components of behaviour change interventions: A study protocol. *Implementation Science*, *6*, 10.

Michie, S., Abraham, C., Whittington, C., McAteer, J., & Gupta, S. (2009). Effective techniques in healthy eating and physical activity interventions: A meta-regression. *Health Psychology*, *28*, 690–701.

Michie, S., Ashford, S., Sniehotta, F.F., Dombrowski, S.U., Bishop, A., & French, D.P. (2011a) A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours – The CALO-RE taxonomy, *Psychology & Health*, *26*, 1479–1498.

Michie, S., Churchill, S., & West, R. (2011b). Identifying evidence-based competences required to deliver behavioural support for smoking cessation. *Annals of Behavioral Medicine*, *41*, 59–70.

Michie, S., Fixsen, D., Grimshaw, J.M., & Eccles, M.P. (2009). Specifying and reporting complex interventions: The need for a scientific method. *Implementation Science*, *4*, 40.

Michie, S., Hardeman, W., Fanshawe, T., Prevost, A.T., Taylor, L., & Kinmonth, A.L. (2007). Investigating theoretical explanations for behaviour change: The case study of ProActive. *Psychology & Health*, *23*, 25–39.

Michie, S., Johnston, M., Francis, J., Hardeman, W., & Eccles, M. (2008). From theory to intervention: Mapping theoretically derived behavioural determinants to behaviour change techniques. *Applied Psychology: An International Review*, *57*, 660–680.

Moher, D., Schulz, K.F., & Altman, D.G. (2001). The CONSORT statement: Revised recommendations for improving the quality of reports of parallel group randomized trials. *Annals of Internal Medicine*, *134*, 657–662.

NICE: National Institute for Health and Clinical Excellence. (2007). Behaviour change at population, community and individual levels. Retrieved from: http://www.nice.org.uk/nicemedia/pdf/PH006guidance.pdf

Painter, A.F. (1972). Modern Classification Theory. In A.F. Painter (Ed.), *Reader in classification and descriptive cataloging* (pp. 100–106). Washington: National Cash Register Company.

Peterson, E. (2006). Beneath the metadata: Some philosophical problems with folksonomy. *D-Lib Magazine, 12*. Retrieved from: http://www.dlib.org/dlib/november06/peterson/11peterson.html

Prochaska, J.O., & Velicer, W.F. (1997). The transtheoretical model of health behavior change. *American Journal of Health Promotion, 12*, 38–48.

Puddephatt, R.J., & Monaghan, P.K. (1986). *The periodic table of the elements* (2nd ed). Oxford: Clarendon Press.

Seberg, O., & Petersen, G. (2007). Assembling the tree of life: Magnitude, shortcuts and pitfalls. In T.R. Hodkinson & J.A.N. Parnell (Eds.), *Reconstructing the tree of life: Taxonomy and systematics of species rich taxa* (pp. 33–46). London: CRC Press.

Simpson, G.G. (1961). *Principles of animal taxonomy.* New York: Columbia University Press.

Sneath, P.H.A., & Sokal, R.R. (1973). *Numerical taxonomy: The principles and practice of numerical classification.* San Francisco: W. H. Freeman.

Spiteri, L.F. (2007). The structure and form of folksonomy tags: The road to the public library catalog. *Information Technology and Libraries, 26*(3), 13–25.

Webb, T.L., & Sheeran, P. (2006). Does changing behavioural intentions engender behaviour change? A meta-analysis of the experimental literature. *Psychological Bulletin, 132*, 249–268.

Webb, T.L., Joseph, J., Yardley, L., & Michie, S. (2010). Using the internet to promote health behaviour change: A systematic review and meta-analysis of the impact of theoretical basis, use of behaviour change techniques, and mode of delivery on efficacy. *Journal of Medical Internet Research, 12*, 1.

World Health Organisation. (2008). *History of the development of the ICD.* Retrieved from: http://www.who.int/classifications/icd/en/HistoryOfICD.pdf

Supplementary Table. The techniques contained within classification systems of behaviour change techniques.

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
Communication/ education	1. Goal or target specified	1. Provide information on consequences of behaviour in general	Passive strategies	Increase coordination to manage interdependence (Contingency Theory	Kernels altering consequences of behaviour *Increasing frequency of behaviour*	1. Goal: set behavioural goal	Addressing motivation
Passive	2. Monitoring/ self-monitoring	2. Provide information on consequences of behaviour relevant to the individual	1. Attitudinal arguments	1. Centralised care management	1. Verbal praise	2. Standard: decide target standard of behaviour (specified and observable)	1. Provide information on consequences of smoking and smoking cessation
1. Lecture	3. Contract	3. Provide information about others' approval	2. Normative arguments	2. Modified medical record system	2. Peer-to-peer written praise	3. Monitoring: record specified behaviour (person has access to recorded data of behavioural performance e.g. from diary)	2. Boost motivation and self efficacy
2. Demonstration	4. Contingencies or incentives for remaining in the programme	4. Provide normative information about other's behaviour	3. Factorial information	3. Workgroup oversight	3. Mystery motivators	4. Record antecedents and consequences of behaviour (social and environmental situations and events, emotions, cognitions)	3. Provide feedback on performance
3. Policy	5. Graded task	5. Goal setting (behaviour)	4. Behavioural skills arguments	4. Pilot testing	4. Public posting of feedback of a targeted behaviour	5. Feedback: of monitored (inc. self-monitored) behaviour	4. Provide rewards contingent on successfully stopping smoking
Active	6. Increasing skills	6. Goal setting (outcome)	5. Threat inducing arguments	Raise awareness of practice change (Diffusion of Innovations)	5. Principal lottery	6. Comparison: provide comparative data (cf standard, person's own past behaviour, others' behaviour)	5. Provide normative information about others' behaviour and experiences
1. Commitment	7. Stress management/ coping skills	7. Action planning	Active strategies	1. Education	6. Safety or performance lottery.	7. Social comparison: provide opportunities for social comparison e.g. contests and group learning	6. Prompt commitment from client there and then

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
2. Discussion	8. Rehearsal of relevant skills	8. Barrier identification/problem solving	1. Condom use skills training	2. External change agent	7. Team competition		7. Provide rewards contingent on effort or progress.
3. Intervention agent	9. Planning, implementation	9. Set graded tasks	2. Interpersonal skills training	Persuade via interpersonal channels/ norms (Diffusion of Innovations/ Theory of Planned Behaviour)	8. Contingent music		8. Strengthen ex-smoker identity
Activators	10. Prompts, triggers, cues	10. Prompt review of behavioural goals	3. Self-management skills training	1. Workgroup develops change	9. Special play	8. Discrepancy assessment: highlight nature of discrepancy (direction, amount) between standard, own or others' behaviour (goes beyond simple self-monitoring)	9. Identify reasons for wanting and not wanting to stop smoking
Individual	11. Environmental changes	11. Prompt review of outcome goals	4. HIV counselling and testing	2. Opinion leader	10. Choral responding	9. Contract: of agreed performance of target behaviour with at least one other, written and signed	10. Explain the importance of abrupt cessation
1. Written activator	12. Social encouragement	12. Provide rewards contingent on effort or progress towards behaviour	5. Condom provision	3. Guidance from manager	11. Mystery shopper	10. Planning: identify component parts of behaviour and make plan to execute each one *or* consider when and/or where a behaviour will be performed i.e. schedule behaviours (not including coping planning – see 11)	11. Measure CO
2. Oral activator	13. Persuasive communication	13. Provide rewards contingent on successful behaviour		Persuade by reinforcing belief that behaviour will lead to desirable results (TPB)	12. Peer-to-peer tutoring	11. Coping planning: identify and plan ways of overcoming barriers (note, this must include identification of specific barriers e.g. "problem solving how to fit into weekly schedule" would not count)	12. Conduct motivational interviewing

Supplementary table (*Continued*)

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
3. Individual goal	14. Information	14. Shaping		1. Data collection and feedback	13. Computer action game	12. Goal review: assess extent to which the goal/target behaviour is achieved, identify the factors influencing this and amend goal if appropriate	Maximising self-regulatory capacity
4. Personal goal	15. Personalised message	15. Prompting generalisation of a target behaviour		2. Financial incentives	14. Correspondence training, "say-do"	13. Discriminative (learned) cue: environmental stimulus that has been repeatedly associated with contingent reward for specified behaviour	1. Facilitate barrier identification and problem solving
5. Competition	16. Modelling by others	16. Prompt self-monitoring of behaviour		3. Performance evaluations	15. Correspondence training, "do-say"	14. Prompt: stimulus that elicits behaviour (inc. telephone calls or postal reminders designed to prompt the behaviour)	2. Facilitate relapse prevention and coping
6. Incentive	17. Homework	17. Prompt self-monitoring of behavioural outcomes		Increase behavioural control (TPB)	*Decreasing frequency of behaviour*	15. Reward: contingent valued consequence i.e. if and only if behaviour is performed (inc. social approval, exc. general non-contingent encouragement or approval)	3. Facilitate action planning/help identify relapse triggers
7. Disincentive	18. Personal experiments	18. Prompt focus on past success		1. Reminder systems	1. Time out	16. Punishment: contingent aversive consequence i.e. if and only if behaviour is not performed	4. Facilitate goal setting
Group	19. Experiential	19. Provide feedback on performance		2.Environmental change	2. Sit and watch	17. Omission: contingent removal of valued consequence i.e. if and only if behaviour is not performed	5. Prompt review of goals
1. Assigned goal		20. Provide information on where and when to perform the behaviour		Designation of change leader	3. Taxes on consumptive behaviours	18. Negative reinforcement: contingent removal of aversive consequence i.e. if & only if behaviour is performed	6. bPrompt self recording

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
2. Team goal		21. Provide instruction on how to perform the behaviour			4. Positive note home for inhibition	19. Threat: offer future punishment or removal of reward contingent on performance	7. Advise on changing routing
3. Competition		22. Model/demonstrate the behaviour			5. Timed rewards for inhibition	20. Fear arousal: induce aversive emotional state associated with the behaviour	8. Advise on environmental restructuring
4. Incentive		23. Teach to use prompts/cues			6. Premack principle	21. Anticipated regret: induce expectations of future regret about non-performance of behaviour	9. Set graded tasks
5. Disincentive		24. Environmental restructuring			7. Response-cost	22. Graded tasks: set easy tasks to perform, making them increasingly difficult until target behaviour performed	10. Advise on conserving mental resources
Consequences		25. Agree behavioural contract			8. Low emotion or "private" reprimands	23. Instruction: teach new behaviour required for performance of target behaviour (not as part of graded hierarchy or as part of modelling) e.g. give clear instructions.	11. Advise on avoidance of social cues for smoking
Individual		26. Prompt practice			9. Stop clock	24. Shaping: build up behaviour by initially reinforcing behaviour closest to required behaviour and systematically altering behaviour required to achieve contingent reinforcement	12. Facilitate restructuring of social life
1. Feedback		27. Use of follow up prompts			10. Law enforcement fine or citation	25. Chaining: build up behaviour by starting with final component; gradually add components earlier in sequence	13. Advise on methods of weight control

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
2. Reward		28. Facilitate social comparison			11. Over-correction or positive practice	26. Behavioural rehearsal: perform behaviour (repeatedly)	14. Teach relaxation techniques
3. Penalty		29. Plan social support/social change			12. Buzzer/noise training	27. Mental rehearsal: imagine performing the behaviour repeatedly	Adjuvant activities
Group		30. Prompt identification as role model/position advocate			Kernels affecting behaviours primarily via antecedents	28. Habit formation: perform same behaviour in same context	1. Advise on stop-smoking medication
1. Feedback		31. Prompt anticipated regret			1. Non-verbal transition cues	29. Role play: perform behaviour in simulated situation	2. Advise on/facilitate use of social support
2. Reward		32. Fear arousal			2. Stop lights	30. Behavioural experiments: testing hypotheses about the behaviour, its causes and consequences, by collecting and interpreting data	3. Adopt appropriate local procedures to enable clients to obtain free medication
3. Penalty		33. Prompt self-talk			3. Boundary cues and railings	31. Modelling: observe the behaviour of others	4. Ask about experience of stop smoking medication
		34. Prompt use of imagery			4. Cooperative, structured peer play	32. Vicarious reinforcement: observe the consequences of others' behaviour	5. Give options for additional or later support
		35. Relapse prevention/coping planning			5. Self-modelling	33. Self talk: planned self-statements (aloud or silent) to implement behaviour change techniques	General aspects of the interaction *Focusing on delivery of the intervention*
		36. Stress management			6. Self-monitoring	34. Imagery: use planned images (visual, motor, sensory) to implement behaviour change techniques (inc. mental rehearsal)	1. Tailor interactions appropriately

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		37. Emotional control training			7. Paragraph shrinking	35. Cognitive restructuring: changing cognitions about causes and consequences of behaviour	2. Emphasise choice
		38. Motivational interviewing			8. Errorless discrimination training	36. Relapse prevention: identify situations that increase the likelihood of the behaviour not being performed and apply coping strategies to those situations	Information gathering
		39. Time management			Kernels affecting behaviours primarily via relational frames	37. Behavioural information: provide information about antecedents or consequences of the behaviour, or connections between them, or behaviour change techniques	1. Assess current and past smoking behaviour
		40. General communication skills training			1. Adjectival noun for belonging to status group	38. Personalised message: tailor techniques or messages from others to individual's resources and context (includes stages of change based information; doesn't include personal plans and feedback)	2. Assess readiness and ability to quit
					2. Public commitment	39. Verbal persuasion/ persuasive communication: credible source presents arguments in favour of the behaviour. Note, there must be evidence of presentation of arguments; general pro-behaviour communication does not count.	3. Assess past history of quit attempts

Supplementary table (*Continued*)

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
					3. "US" and "THEM" role framing	40. Social support (instrumental): others perform component tasks of behaviour or tasks that would compete with behaviour e.g. offering childcare	4. Assess withdrawal sympotoms
					4. Graphic/node maps	41. Social support (emotional): others listen, provide empathy and give generalised positive feedback	5. Assess nicotine dependence
					5. MI	42. Decision-making: generate alternative courses of action, and pros and cons of each, and weigh them up.	6. Assess number of contacts who smoke
					6. Media associating behaviour with immediate negative social outcomes	43. Coping strategies: behaviours undertaken to avoid or reduce stressors	7. Assess attitude to smoking
					Kernels affecting behaviours primarily via physiology		8. Assess level of social support
					1. Pleasant greeting with or without positive physical touch	44. Stress management: behaviours undertaken to reduce stressors or impact of stressors	9. Explain how tobacco dependence develops
					2. Massage, brushing or stroking	45.Relaxation: systematic instruction in physical and cognitive strategies to reduce sympathetic arousal, and to increase muscle relaxation and a feeling of calm	10. Assess physiological and mental functioning
					3. Turtle technique	46. Desensitisation: exposure to threatening experiences	General communication

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
					4. Omega-3 fatty acid supplementation or increased fish consumption	47. Systematic desensitisation: graded exposure to increasingly threatening experiences	1. Build general rapport
					5. Zinc supplementation	48. Time management: action planning applied to the perceived problem of shortage of time	2. Elicit and answer questions
					6. "Rough and tumble" free play with higher status conspecific	49. Motivational interviewing: elicit self-motivating statements& evaluation of own behaviour to reduce resistance to change	3. Explain the purpose of CO monitoring
					7. Aerobic play or behaviour	50. Environmental change: change the environment in order to facilitate the target behaviour (other than prompts, rewards and punishments e.g. choice of food provided)	4. Explain expectations regarding treatment programme
					8. Nasal breathing	**51 Set homework task**	5. Offer/direct towards appropriate written materials
					9. Progressive muscle relaxation	52. Non-specific social support (only if additional to 40 and 41)	6. Provide information on withdrawal symptoms
						53 General information about the behaviour and behaviour change (other than 37)	7. Use reflective listening
						54. General problem-solving	8. Elicit client views
						55. Anti-depression skills training	9. Summarise information/confirm client decisions

Supplementary table (*Continued*)

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
						56. Biofeedback	10. Provide reassurance
						57. Differential reinforcement	
						58. Escape	
						59. Extinction	
						60. Flooding	
						61. Group contingencies	
						62. Implosive therapy	
						63. Avoidance	
						64. Counter-conditioning	
						65. Distraction	
						66. Exposure	
						67. Fading; thinning	
						68. Flooding in imagination	
						69. Habit reversal	
						70. Negative punishment	
						71. Non contingent delivery of reinforcing stimuli	
						72. Overcorrection	
						73. Peer-administered contingencies	
						74. Problem identification	
						75. Rational emotive therapy	
						76. Reinforcer sampling	
						77. Response cost	
						78. Response priming	
						79. Satiation	
						80. Screening	
						81. Social skills training	
						82. Stress inoculation program	
						83. Symbolic desensitization	
						84. Thought stopping	
						85. Time out	
						86. Token economy	

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
						87. Activity scheduling	
						88. Adventitious reinforcement / superstitious conditioning	
						89. Altering antecedent chains	
						90. Anger control training	
						91. Assertion training	
						92. Buddy system	
						93. Clarification (supportive therapy)	
						94. Classical conditioning	
						95. Community reinforcement	
						96. Covert conditioning	
						97. Covert sensitisation	
						98. Deflection techniques	
						99. Discrimination training	
						100. Emetic therapy	
						101. Encounter (existential analysis)	
						102. Fishbowl	
						103. Fogging	
						104. Functional communication training	
						105. Functional family therapy	
						106. Identification (psychoanalysis)	
						107. Instigation	
						108. Interpretation (psychoanalysis)	
						109. Least-to-most prompting	
						110. Lottery	
						111. Most to least prompt sequences	
						112. Motivational techniques	

Supplementary table (*Continued*)

Geller et al. (1990)	Hardeman et al. (2000)	Abraham and Michie (2008) (40-item extension)	Albarracín et al. (2005)	Leeman et al. (2007)	Embry and Biglan (2008)	Michie et al. (2008)	Michie et al. (2011)
						113. Multiple exemplar training (generalisation)	
						114. Natural maintaining contingencies (generalisation)	
						115. Negotiation training	
						116. Paradoxical instructions	
						117. Paradoxical intention (behaviour therapy)	
						118. Positive reinforcement	
						119. Positive scanning	
						120. Premackian reinforcers	
						121. Rate reduction	
						122. Reassurance (supportive therapy)	
						123. Recapitulation	
						124. Reframing	
						125. Reinforcer displacement	
						126. Response priming	
						127. Restitution	
						128. Rule release	
						129. Self-exploration	
						130. Self-help	
						131. Small group exercises	
						132. Stimulus generalisation	
						133. Stimulus narrowing	
						134. Systematic rational conditioning	
						135. Thinning	
						136. Turtle technique	
						137. Vicarious punishment	