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Evolutionary learning processes as the foundation for behaviour change

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ABSTRACT
We argue that the active ingredients of behaviour change interventions, often called behaviour change methods (BCMs) or techniques (BCTs), can usefully be placed on a dimension of psychological aggregation. We introduce evolutionary learning processes (ELPs) as fundamental building blocks that are on a lower level of psychological aggregation than BCMs/BCTs. A better understanding of ELPs is useful to select the appropriate BCMs/BCTs to target determinants of behaviour, or vice versa, to identify potential determinants targeted by a given BCM/BCT, and to optimally translate them into practical applications. Using these insights during intervention development may increase the likelihood of developing effective interventions – both in terms of behaviour change as well as maintenance of behaviour change.

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Within health psychology, there are ongoing efforts to develop taxonomies of the active ingredients of behaviour change interventions (Kok et al., 2016; Michie et al., 2013). Some refer to these active ingredients as behaviour change techniques (BCTs), which are defined as 'an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour' (Michie et al., 2013, p. 82). The use of the adjective 'irreducible' is in line with the initial idea behind the BCT taxonomy to address 'the need for a common vocabulary in terms of which content components of behaviour change interventions can be defined and described' (Abraham & Michie, 2008, p. 380). In other words, it is a *coding* taxonomy, which implies that the distinction between BCTs has to be very clearly defined: the goal is to achieve categories that are mutually exclusive and ideally exhaustive. Others, however, refer to these tools as theory-based methods, or behaviour change methods (BCMs), which are defined as 'general techniques or processes that have been shown to be able to change one or more determinants of behaviour' (Kok et al., 2016, p. 299). This is suitable for a *development* taxonomy with the goal 'to provide a toolbox that most efficiently enables planners to select the method that fits their circumstances' (Kok et al., 2016, p. 304). These theory-based methods are drawn from different theories and may overlap. These differences in their nature render BCMs most appropriate for the development of behaviour change interventions and BCTs for the coding of behaviour change interventions.

However, the concept of a 'BCM' and a 'BCT' is similar, and this article deals with both. As umbrella term, we will use Behaviour Change Principle or Behaviour Change Principle set (both abbreviated to BCP). A BCP is any principle or any set of principles that can be applied to change behaviour, or more

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accurately, determinants of behaviour, with the assumption that it will be effective. Stated more strongly, we would argue that any intervention that successfully changes one or more determinants of behaviour must therefore involve one or more BCPs. It is important to note this, because this touches upon a core difference between BCMs and BCTs. The idea is that BCMs are effective if the parameters for use are properly respected when translating BCMs to practical applications (Kok et al., 2016). In this vocabulary, there is a clear distinction between the active ingredients (the BCM) and the operationalisation of these principles (the practical application; see Figure 6). The description of BCTs, on the other hand, 'is precise enough to achieve reliability of recognition but the definition does not require that BCTs be effective' (Michie, Johnson, & Johnston, 2015, p. 25), which is one of the reasons BCTs are not suited for intervention development. BCTs, therefore, are somewhat of an amalgam of BCMs (hypothetically effective methods of behaviour change) and practical applications (operational definitions) that may include inactive ingredients. Those BCTs that are ineffective therefore involve no BCPs; and of those that are effective, their description may contain elements that are not required to adequately leverage the relevant BCPs.

A similarity between BCTs and BCMs is that they both explicitly provide for clustering of BCPs into 'higher level' BCPs (Kok, Gottlieb, Panne, & Smerecnik, 2012; Michie et al., 2013). In the current contribution, we will argue that this 'clusterability' belies a more fundamental property of BCPs: a BCP can be placed on a continuum of psychological aggregation (Peters & Crutzen, 2017b). Furthermore, we will argue that on this continuum, neither BCTs nor BCMs come close to the lowest level (i.e., are irreducible components). Instead, we will introduce what we perceive to be the foundation of behaviour change: evolutionary learning processes (ELPs). We will explain why it is important to understand how these ELPs operate when applying BCPs at higher levels of psychological aggregation (such as BCTs and BCMs). More generally, we will show how a perspective on BCPs analogous to pragmatic nihilism is useful when thinking about behaviour change (Peters & Crutzen, 2017b).

We will illustrate applying this perspective to two steps of intervention development, reflected by two subfields of (health) psychology: behaviour explanation and behaviour change (Glanz & Bishop, 2010). First, we will illustrate that a better understanding of these ELPs and their manifestation in higher level BCPs is useful to select the appropriate BCPs during intervention development. In research, this understanding can help to link BCPs to determinants (Kok et al., 2016) or mechanisms of action (Michie, Johnston, Rothman, Kelly, & De Bruin, 2016). Second, we argue that BCPs work through psychological processes that can be derived from ELPs. So, during intervention development, when translating BCPs to practical applications, these psychological processes need to be taken into account. Selecting BCPs that are suitable to target relevant determinants of a certain behaviour and optimally translate them into practical applications is essential to increase the likelihood of developing effective interventions targeted at that behaviour (Abraham, 2015; Bartholomew Eldredge et al., 2016). In research, awareness of lower-level BCPs enables researchers to craft matched stimuli for control conditions to ensure comparability (Michie, Prestwich, & De Bruin, 2010).

Levels of psychological aggregation

Both BCTs and BCMs are presented as taxonomies that are particular systems of classification (Kok et al., 2016; Michie et al., 2013). The BCT taxonomy comprises an extensive hierarchical classification. For example, the BCTs 'Demonstration of the behaviour' and 'Social comparison' are both grouped under the higher level cluster labelled 'Comparison of behaviour' (Michie et al., 2013). 'Comparison of behaviour' has a higher level of psychological aggregation than the individual BCTs that are grouped in this cluster (Figure 1). The BCPs 'Social Comparison' and 'Demonstration of the behaviour' each engage specific sets of psychological processes that may result in changes in psychological determinants. Using BCP 'Comparison of behaviour' involves the psychological processes engaged by both 'sub-BCPs'.

Also within the taxonomy of BCMs there are different levels of psychological aggregation, as acknowledged by Kok et al.: 'methods may vary in their level of specificity, and may even encompass

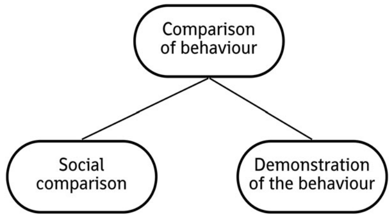

Figure 1. Example of higher level clustering of BCTs.

each other' (Kok et al., 2016, p. 304). For example, 'Participatory problem solving' (at a higher level of psychological aggregation) is often comprised of 'Goal setting' and 'Feedback' (each at a lower level of psychological aggregation) (Kok et al., 2012) (Figure 2).

So, level of psychological aggregation is an important but implicit dimension in both taxonomies. This mirrors the importance of level of psychological aggregation in health psychology theory regarding determinants of behaviour (Peters & Crutzen, 2017b). In the Reasoned Action Approach, for example, intention has the highest level of psychological aggregation, followed by attitude, experiential attitude, and ultimately ending with behavioural beliefs at the lowest level of psychological aggregation (Fishbein & Ajzen, 2010). In many theories of behaviour explanation, the smallest units that are distinguished are on the same level of psychological aggregation as these 'beliefs' in attitude research (Peters & Crutzen, 2017b). Such lower levels of psychological aggregation are crucial, because those very specific aspects of human psychology are what is used in operationalisations and intervention messages (Crutzen & Peters, 2017). However, BCPs as defined in the BCM and BCT traditions are defined at a much higher level of psychological aggregation, a level more akin to that of determinants such as attitude and self-efficacy. In fact, in the intervention mapping (IM) framework for intervention development and description, the intersection of behaviour explanation theory with behaviour change theory explicitly occurs at the determinant level. In IM, the intervention developer first identifies the beliefs that predict the target behaviour, and then identifies the determinants these beliefs are a part of to search for BCPs. By analogy, this raises the question whether BCPs are in fact at the lowest level of psychological aggregation, as has been argued for BCTs (Michie et al., 2013). In other words, do higher level clusters (Michie et al., 2013) consist of irreducible components (e.g., BCTs), or is it useful to distinguish lower levels of psychological aggregation, on which these BCPs in turn rely? We argue the latter: BCPs rely on evolutionary learning principles (ELPs).

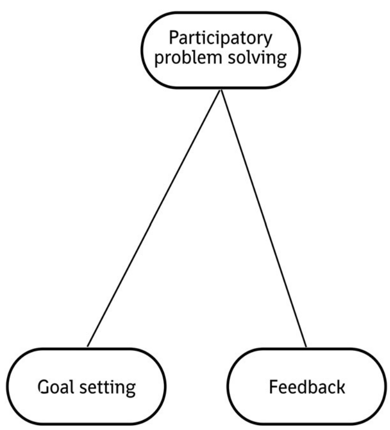

Figure 2. Example of higher level BCM comprising lower-level BCMs.

A reinforcement learning perspective on behaviour

Before explaining how BCPs rely on ELPs, we first take a step back and explain how behaviour results from brain activity. In short, all overt behaviour results from activation patterns of firing neurons in the motor cortex, and activation patterns in the motor cortex are the result of activation patterns elsewhere in the brain (Pinel, 2011). When people learn, this also results in changes in activation patterns of firing neurons. This idea is based on the role of enzymatic neurons in the selection circuits model (Kampfner & Conrad, 1983). According to this model, the firing properties of neurons are controlled by postulated enzymes called excitases. Learning is mediated by changes in the excitase composition of enzymatic neurons. These changes are guided by processes analogous to evolution by variation and selection of networks:

> Different types of excitases may be added to or deleted from enzymatic neurons in these networks by various types of random processes (i.e., variation processes). The behaviour of the organism can be controlled by any one or any combination of these networks. The functional value of each of the networks is evaluated on the basis of the organism's performance. The excitase contents of the best performing networks are retained and transferred to the less fit networks (i.e., selection processes). (Kampfner & Conrad, 1983, pp. 935–936; text between parentheses added by us)

This is in line with a reinforcement learning perspective on behaviour: people acquire complex behaviours by learning to obtain (real or conjectured) rewards and to avoid punishments (Vlaev & Dolan, 2015). Subsequently, the brain can decide which action to take based on 'computation' of value (i.e., expected rewards) (Rangel, Camerer, & Montague, 2008). In a colloquial way, the use of words such as 'decide' and 'value' might give the impression that this only concerns goal-directed behaviour based on reflection. The same applies, however, to habitual behaviours (Gardner, 2015). Moreover, the values might be based on various rewards such as comfort, control, status, and belonging (Vlaev & Dolan, 2015). Thus, despite choice of words, no rationality, logic, or reflection is implied: these theoretical foundations are not bounded to specific aspects of human behaviour or psychology.

The evolution of ELPs

The fact that various rewards are valuable to an organism and that the brain evolved to obtain those rewards says nothing about the learning process as such (i.e., *how* the brain changes to optimise future reward obtainment). However, it is possible to identify new, distinct learning processes that evolved over time, such as classical conditioning (see Table 1 for an overview). The evolution of these learning processes was needed to solve particular problems in the niches in which organisms evolved (e.g., how to find food? Where to sleep safely?). There are enough regularities in these niches for distinct learning processes to evolve on top of existing learning processes (Aunger & Curtis, 2015). For example, despite the (self-perceived) sophistication of our learning, humans still use simple cue-response reflexes that were already present in invertebrates. Evolution did not do away with reflexes when deliberative cognitions evolved. Each of these learning processes enabled specific behavioural novelties that facilitated organisms' adaptation to a changing environment over time. Learning processes refer to different types of learning, different types of memory, as well as abilities to mentally represent phenomena in the external world. Because these learning processes have an evolutionary function, we label them as evolutionary learning processes (ELPs). Reflective learning is the only ELP that is unique to humans; all the other ELPs were already exhibited in animal behaviour long ago. Table 1 provides an overview of ELPs and behavioural novelties in chronological order (Aunger & Curtis, 2015), as well as examples of how ELPs are still relevant in enabling human behaviour in everyday life.

BCPs rely on ELPs

The examples of ELPs that are provided in Table 1 refer to learning in everyday life. There are differences between people in the way and the extent to which they learn to behave, of course. In other words, some people are better in adapting than others. However, learning in itself is undeniably needed to behave appropriately in the environment one lives in. This is also relevant for health, which can be defined as 'the ability to *adapt* and to self-manage in the face of social, physical, and emotional challenges' (Huber et al., 2011, p. 1, our emphasis). Interventions in the field of health psychology therefore often stimulate people to adapt their behaviour (i.e., they are often aimed at behaviour change). In fact, these interventions should be seen as stimulating an 'intensified

Table 1. Evolutionary learning processes and behavioural novelties (derived from Aunger and Curtis (2015)) in chronological order.

Evolutionary learning process	Explanation	Behavioural novelty	Example
Habituation/ sensitisation	Learning not to respond to a stimulus (habituation) or an increased magnitude of a response or a lowered threshold to respond (sensitisation)	Algorithmic responses to stimuli: repeated stimuli are likely due to the same cause. If this has not resulted in harm/benefit, then this is likely to be the same in future contacts	The creaking of the stairs in an old hotel might be irritating at first, but you might not even notice the creaking sound anymore after a couple of nights
Classical conditioning	Learning that two stimuli are associated	Movement without (unconditioned) stimulus being present: a (conditioned) stimulus, which previously had little effect on behaviour, is able to produce a reflexive response (e.g., a fear response)	The mere sight of an ashtray might lead to craving for a cigarette
Operant conditioning	Learning an association between a stimulus and an outcome	Cue-induced behaviour complexes: certain behavioural responses are more likely to produce beneficial outcomes	If a screaming child attracts its parents' attention, then the child learns that screaming leads to getting attention
Affective learning/ emotional memory	Learning characteristics of an event (affective learning) and affect associated with (emotional memory) an outcome	Controlled responses to local circumstances: linking beneficial outcomes to temporal and social aspects (e.g., places, times, and other actors)	Hearing a song on the radio might bring back memories of a party where you met your high school lover
Procedural memory	Learning how to conduct complex behavioural sequences	Skill acquisition: acquiring a skill requires attention, but after repeated practice the skill becomes nearly automatic and requires less cognitive resources	Driving a car for the first time requires a lot of attention, but after practice you effortlessly overtake another car
Cognitive maps	Learning to find one's way reliably by using features of the environment and using rules to estimate relationships between points in the environment	Territory-related behaviours: the ability to select the most economical path in familiar and unfamiliar settings	Being able to explain somebody how to get to the restaurant where you agreed to meet (even if you never took that route before)
Vicarious conditioning	Learning from behavioural strategies used by others	Behaviour contingent on other agents: the ability to learn from others who might have locally relevant information	Knowing where to find cream and sugar in a coffee shop by watching others before you in line locate that area
Abstract concept learning/declarative memory	Learning representations *about* objects and events (abstract concept learning) and storing this information (declarative memory)	Ordered goal-achievement sequences: being able to categorise objects and events requires less cognitive resources because they can transfer appropriate responses to novel instances	If you buy groceries at a different store than usual, you still know how to behave (e.g., adding products to your shopping cart, paying at the cashier's desk)
Reflective learning/ autobiographical memory	Learning from past behaviour and feedback in order to plan future behaviour (reflective learning) and storing these reflections (autobiographical memory)	Symbol-based behaviour: Being able to engage in sophisticated long-term planning that enables, for example, art and music	Writing a novel

form' of learning, comparable to deliberate stimulations of learning that have been used by humans long before they were defined and studied, and have enabled natural adaption even before that by humans and other organisms. For example, Pavlov's initial observations of classical conditioning were serendipitous; a particular pattern of footsteps happened to be associated with food being provided to the dogs in the lab. Later on, Pavlov started manipulating patterns in order to get more insight into this type of learning (Todes, 2014). Manipulations of these patterns could be seen as an early type of behaviour change intervention relying on ELPs. In a more general sense, BCPs that have an impact on (determinants of) behaviour rely on ELPs. To put it strongly, (people's) capability to change consists of ELPs, and these operate through psychological processes (as explained later on). The behaviour of the dogs in Pavlov' lab would not have changed if no learning had taken place. This applies to BCPs aimed directly at the individual (e.g., guided practice, where individuals practice a behaviour with supervision) as well as to changes in response to the environment (e.g., when certain cues are removed; Moore & Depue, 2016).

For example, habituation/sensitisation is an ELP that uses the fact that environmental input over time might lead to different neurobiological reactions: depending on the parameters, those reactions can intensify (sensitisation) or fade away (habituation). This is also reflected in people's behaviour. For example, when eating the same food during a meal, people decrease their consumption over time. Habituation plays an important role in this phenomenon (besides satiety), because food variety slows down the habituation process and is considered to contribute to the development and maintenance of obesity (Raynor & Epstein, 2001). Table 2 provides an overview of how BCPs (Bartholomew Eldredge et al., 2016) rely on different ELPs. This is not meant to be a comprehensive overview of all existing BCPs, but merely serves to demonstrate how BCPs rely on ELPs.

ELPs are at a lower level of psychological aggregation, followed by BCMs and BCTs at higher levels. In Table 2, we have provided two examples of BCPs for each ELP in order to illustrate that different BCPs can rely on the same ELP. The overlap between BCPs (e.g., providing cues and stimulus control; Figure 3) might become apparent when they are translated to practical applications. It is also possible that a BCP relies on more than one ELP (Figure 4). For example, planning coping responses requires identification of high-risk situations and practice of coping responses (Bartholomew Eldredge et al., 2016). This BCP relies on reflective learning, because people need to be able to derive high-risk situations from their past behaviour. However, it also relies on procedural memory, because practising of coping responses might require people to learn complex behavioural sequences. Finally, at an even higher level of psychological aggregation, there are overarching BCPs that combine multiple lower-level BCPs (Figure 5). For example, motivational interviewing often includes goal setting and planning coping responses (Hardcastle, Fortier, Blake, & Hagger, 2017).

Using ELPs when selecting BCPs

The reliance of BCPs on ELPs is not only interesting from a theoretical point of view, but also relevant for intervention development. During intervention development, BCPs are linked to the determinants of behaviour that need to be targeted in an intervention. Some BCPs are more appropriate for certain determinants (Bartholomew Eldredge et al., 2016). We argue that this is because these BCPs rely on different ELPs that are more relevant for certain determinants, for example, because those determinants are defined as aspects of memory or psychological processes of a type that the relevant ELPs act on. In other words, a better understanding of ELPs is useful to select the appropriate BCPs during intervention development. Although this required match between determinants and BCPs is already acknowledged in several approaches to plan behaviour change interventions (Aunger & Curtis, 2016; Bartholomew Eldredge et al., 2016), the concept of ELPs provides a systematic way of thinking about this match. In short: we submit that ELPs are the missing link to explain why a given BCP is more likely to change some determinants (or 'mechanisms of action') than others. However, it is important to keep in mind that although ELPs are useful categories of learning processes, learning processes are not modular any more than psychological variables are (Peters & Crutzen, 2017a). Construing

Table 2. Examples of behaviour change methods (derived from Bartholomew Eldredge et al. (2016)) relying on evolutionary learning processes.

Evolutionary learning process	Example of behaviour change method	Explanation
Classical conditioning	Providing cues	Assuring that the same cue is present at the time of learning and the time of retrieval facilitates an appropriate response at the time of retrieval, because the cue serves as a conditioned stimulus
	Stimulus control	Encouraging removing cues for unhealthy habits (conditioned stimuli for unhealthy behaviour) and adding prompts for healthier alternatives (conditioned stimuli for healthy behaviour)
Operant conditioning	Reinforcement	Linking a behaviour to any consequence that increases the behaviour's rate, frequency, or probability
	Counterconditioning	Encouraging the learning of healthier behaviours that can substitute for unhealthy behaviours
Affective learning/emotional memory	Dramatic relief	Encouraging emotional experiences, followed by reduced affect or anticipated relief if appropriate behaviour is conducted
	Fear arousal	Arousing negative emotional reactions in order to promote self-protective behaviour
Procedural memory	Guided practice	Prompting to rehearse and repeat the behaviour various times, discuss the experience, and provide feedback
	Set graded tasks	Setting easy tasks and increase difficulty until target behaviour is performed
Cognitive maps	Advance organisers	Presenting an overview of the material that enables a learner to activate relevant schemas so that new material can be associated
	Using imagery	Using artefacts that have a similar appearance to some subject (e.g., memorising a self-care process by attaching the steps to landmarks on a familiar daily route)
Vicarious conditioning	Modelling	Providing an appropriate model that is reinforced for the desired behaviour
	Behavioural journalism	Using appropriate role-model stories of behaviour change based on authentic interview with the target group
Abstract concept learning/ declarative learning	Stereotype-inconsistent information	Providing positive examples from the stigmatised group
	Interpersonal contact	Bringing people in contact with members of the stigmatised group
Reflective learning/ autobiographical memory	Elaboration	Stimulating the learner to add meaning to the information that is processed
	Self-reevaluation	Encouraging assessment of one's self-image with and without an unhealthy behaviour

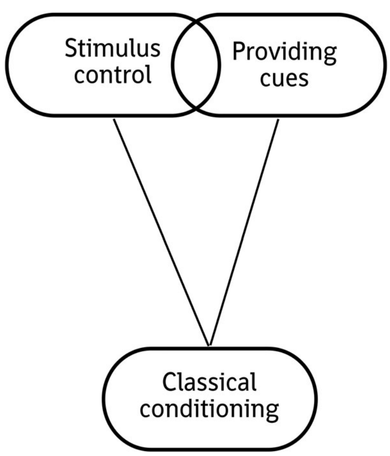

Figure 3. Example of overlap between BCPs relying on the same ELP.

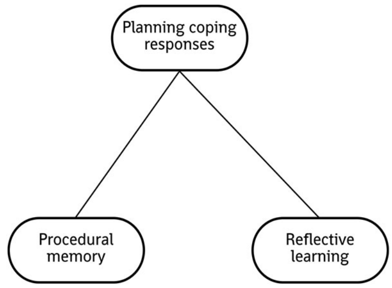

Figure 4. Example of a BCP relying on more than one ELP.

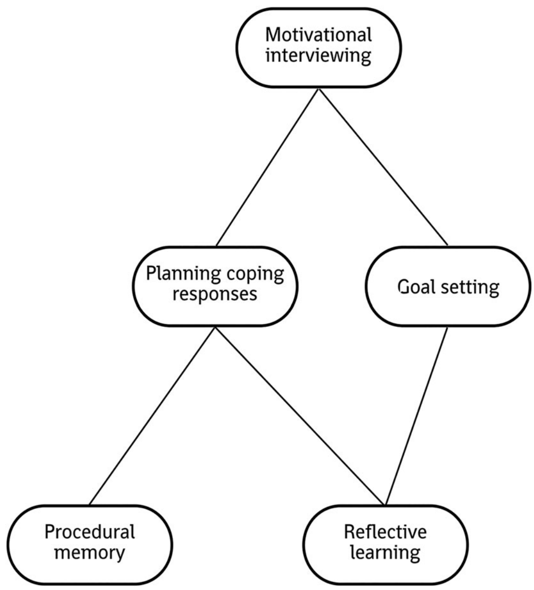

Figure 5. Example of overarching BCP that combines multiple lower-level BCPs.

psychological variables and processes as modular entities is intuitive, and moreover, required to enable systematic study and communicating one's findings – but this convenience afforded by modularity does not also afford it truthfulness.

In the debate about pragmatic nihilism (De Vries, 2017; Fried, 2017; Gruijters, 2017; Peters & Crutzen, 2017a, 2017b; Trafimow, 2017), it has been argued that psychological constructs need not exist as such to have value for behaviour change. This same pragmatic position can be taken regarding BCPs. Psychology did not evolve to be conveniently described using categories, and that applies both to variables and processes. Therefore, it is unlikely that BCPs can be pinpointed as such: instead, they are useful descriptions of ways to leverage aspects of human psychology in order to achieve behaviour change. It follows from this position that there is nothing special about the level at which BCTs and BCMs are currently described, about the level at which ELPs are described, or about the level at which clustered BCTs and BCMs are described. These levels conveniently lend themselves for description, coding, research, and intervention development, but that does not mean that these levels therefore have a central role in human psychology. In other words, '[w]hat is convenient when thinking about or measuring aspects of human psychology does not, by virtue of the fact that it comes natural to the scientists doing the science, have to be what is true' (Peters & Crutzen, 2017a, p. 142).

This also means that other levels can usefully be distinguished in between the level of ELPs and the level of BCPs. For example, Figure 5 shows that the BCP planning coping responses uses two ELPs: reflective learning and procedural memory. Intermediate levels that can be distinguished are, for example, identify high-risk situations, identify most effective coping responses, and decide to monitor for high-risk situations and, if one arises, engage in the corresponding coping response. Each of these BCPs in itself can be expected to achieve some changes in relevant psychological determinants (which may then translate to behaviour change). However, when used collectively they satisfy a number of practical conditions (i.e., high-risk situations are not only identified, but solutions are prepared as well) that together represent a particularly high likelihood that the changes in determinants result in behaviour change. For this reason, planning coping responses is a BCP at a more useful level than the three BCPs distinguished at this lower level. Although the levels at which BCPs are described do not necessarily reflect crucial levels at which human psychology functions, these levels do provide information about where useful synergies exist that can effectively be exploited in behaviour change.

This is reflected by current descriptions of BCPs in the literature (see e.g., Kok et al., 2016; Michie et al., 2013) that already clearly show combinations of multiple lower-level BCPs. The developers of those taxonomies will generally have aimed to formulate their BCP descriptions such that they contain all those steps that are necessary for the BCP to be optimally effective. For example, when an intervention developer misapplies coping planning and instead only includes the identification of high-risk situations, the intervention will still change aspects of participants' psychology, and this will still translate to behaviour change for some participants. However, if the BCP description is followed completely, the effectiveness can be expected to be higher. For some BCPs, certain lower-level BCPs are crucial. For example, in the case of modelling, if the participants do not identify with the role model, no behaviour change can be expected, as the ELP vicarious conditioning requires an appropriate model to take place. Such conditions for effectiveness are explicitly contained in BCM descriptions as parameters for use (Kok et al., 2016).

Our argument, therefore, extends beyond the importance of understanding ELPs: to optimally apply BCPs in behaviour change interventions, and to study BCPs in a methodologically correct manner, requires understanding the involved psychology (see next section for more details). ELPs are a useful endpoint of sorts, in that they are clearly identifiable in many organisms yet maintain their functionality in humans, and as such, are usefully seen as the most specific level. However, evolution and human psychology do not care for convenient levels or categories, and lower-level processes than ELPs are involved in behaviour change. These lower-level processes combine in different configurations that exhibit some consistency in function that are usefully captured by ELPs (e.g., reflective learning), and permutations of (aspects of) ELPs combine in BCPs at a higher level (e.g., identify high-risk situations) and eventually in BCMs, BCTs (e.g., planning coping responses), and clusters of BCMs and BCTs (e.g., motivational interviewing). Thus, familiarity with the literature concerning a BCP (i.e., the relevant fundamental psychological studies, e.g., from cognitive psychology), and therefore being aware of lower-level BCPs that are potentially useful to distinguish and understand, can considerably facilitate behaviour change research and intervention development. We will illustrate how knowledge of ELPs underlying a number of BCPs can be beneficial when selecting the appropriate BCPs during intervention development.

The older ELPs (e.g., classical conditioning, operant conditioning) are most appropriate to change *habitual, automatic, and impulsive behaviours*, or determinants defined as aspects of human psychology related to habituation and sensitisation. It is important to note that although people might not be aware of the learning processes taking place at the brain level, this does not mean that they cannot actively contribute to learning. For example, when using stimulus control to encourage people to remove cues for unhealthy habits, it is essential that they have insight in the cues leading to automatic responses (Papies, 2016). This insight can then be used in an intervention recommending people to remove their ashtrays or other cues that might lead to craving for a cigarette.

BCPs that rely on affective learning (e.g., fear arousal, dramatic relief) are most appropriate to change *awareness and risk perception*. Affective learning evolved after the older ELPs and it was the first step in evolution of organisms becoming aware of their own behaviour. Nowadays, these BCPs can still lead to increased attention (Kessels, Ruiter, & Jansma, 2010), but this is useless if people are not confident they can successfully perform an alternative behaviour to eliminate the threat. Therefore, it is not surprising that subsequently ELPs such as procedural memory and cognitive maps evolved, as these are most appropriate to improve *skills and knowledge*, respectively. Next, vicarious conditioning resulted in people learning from each other, which is one of the sources of *self-efficacy* (Bandura, 1997).

Later in evolution, abstract concept learning evolved. Being able to categorise is beneficial in the sense that people need less cognitive resources in order to know how to behave in a certain situation that is similar to situations they have encountered before. However, it can also result in stereotyping that affects people's judgement and behaviour (Kunda & Spencer, 2003). Hence, BCPs aimed at reducing *stigma* often rely on abstract concept learning (Bos, Schaalma, & Pryor, 2008).

Finally, reflective learning evolved. This is highly relevant for long-term *planning* and to achieve larger *goals* in life (e.g., McEwan et al., 2016). On the one hand, this is just one of the many ELPs that can be used in behaviour change interventions. On the other hand, it is an ELP that uses a unique capability of humans: to reflect on their own behaviour and to behave in a certain way to achieve long-term goals. Table 3 provides an overview of the ELPs and their potential intervention targets. It is important to keep in mind that BCPs can rely on more than one ELP (Figure 4) and that there are overarching BCPs that combine multiple lower-level BCPs and ELPs (Figure 5).

Using ELPs when applying BCPs

The link between ELPs and BCPs might come across as a simple mix-and-match exercise that can be used when *selecting* the appropriate BCPs during intervention development. For example, as explained above, BCPs relying on operant conditioning can be used when targeting a habitual behaviour. However, *applying* these insights during intervention development requires a thorough understanding of ELPs. For example, when using BCPs that rely on operant conditioning, one should be familiar with differences between performance of fixed-ratio, variable-ratio, fixed-interval, and variable-interval schedules (Ferster & Skinner, 1957) as well as the existence of the partial-reinforcement effect (Humphreys, 1939). The same goes, for example, for ELPs relying on different types of memory. In fact, memory research focusing on different levels of processing is a branch of research on its own (Craik & Lockhart, 1972). This implies that development of intervention components necessitates in-depth insight into fundamental research from fields such as experimental psychology and cognitive psychology (Johnston, 2016).

Applying BCPs is not a matter of selecting and combining them into an attractive intervention. BCPs are not psychological tricks that can be reliably employed to achieve behaviour change, and in fact do not even have an 'effectiveness' in and of themselves (Peters, De Bruin, & Crutzen, 2015). Instead, learning processes are exploited that evolved for altogether different purposes. Because behaviour change interventions must successfully engage those learning processes, successfully mimicking the way in which people learn in everyday life and the situations for which those

Table 3. Evolutionary learning processes and their potential intervention targets.

Evolutionary learning processes	Potential intervention targets
Habituation/sensitisation, classical conditioning, and operant conditioning	Habitual, automatic, and impulsive behaviours
Affective learning/emotional memory	Awareness and risk perception
Procedural memory and cognitive maps	Skills and knowledge
Vicarious conditioning	Self-efficacy
Abstract concept learning/declarative memory	Stigma
Reflective learning/autobiographical memory	Planning and goals

learning processes evolved is crucial, as these are necessary conditions for effectiveness. This mimicking requires an in-depth understanding of the psychological processes relevant to the chosen BCPs. The method specifications in the IM taxonomy aim to capture these crucial conditions for effectiveness, referred to as parameters for use (Kok et al., 2016). These parameters for use capture those aspects that are crucial to successfully engage the psychological processes that constitute the relevant method of behaviour change. For example, in the case of modelling, one of the parameters for use decrees that the model must be positively reinforced. This makes sense when considering the background of vicarious learning. Selectively mimicking behaviour with positive consequences for those executing it is a superior strategy (from an evolutionary point of view) to mimicking all observed behaviour (Peters & Kok, 2016).

When translating BCPs into practical applications to be used in an intervention, it is crucial to take these parameters for use into account (Figure 6). This is necessary to make sure that the BCPs are optimally translated, meaning that the appropriate psychological processes are targeted. These psychological processes can be derived from ELPs. For example, providing stereotype-inconsistent information (i.e., positive examples from the stigmatised group) as a way to reduce stigma relies on abstract concept learning (Table 2). This abstract concept learning is only effective when there are many different examples, and these examples are not too discrepant from the original stereotype (Bos et al., 2008; Kok et al., 2016). If the BCP of providing stereotype-inconsistent information is operationalised in such a way that only few different examples are used, people might think that just one exception is presented. If the examples are too discrepant, people might deem the information to be irrelevant regarding their views on the stigmatised group. At the ELP level of psychological aggregation, this is explained by the dynamics of declarative memory. Presentation of few exemplars that share many characteristics with existing schemata results in assimilation into those existing schemata, whereas presenting sufficient and sufficiently deviant exemplars results in accommodation of the schemata (Axelrod, 1973). Hence, using enough and the right examples is essential to engage the appropriate psychological processes.

Implications of the BCP aggregation continuum and ELPs as foundation

Viewing BCPs as being located on a continuum, with BCPs consisting of lower-level BCPs and ELPs being the smallest (currently identified) building blocks, has a number of implications.

First, construing BCPs as configurations of lower-level BCPs in varying intensities explains overlap between BCPs. If multiple BCPs utilise the same ELPs some degree of overlap is inevitable. This means that in coding taxonomies, obtaining mutual exclusivity of BCPs at higher levels than the lowest level necessarily requires artificially imposing a discontinuity that does in fact not exist in the BCPs themselves (Figure 6). Acknowledging ELPs in such taxonomies is useful in this respect, but as ELPs may turn out not to be the lowest level, some blurring of the lines may remain inevitable even then.

Second, if to be effective BCPs need to successfully engage lower-level BCPs (with ELPs representing the lowest level currently distinguished), this means that listing methods or techniques of behaviour change that are used in an intervention is insufficient to replicate intervention efforts. Such lists are not informative about the way in which the methods or techniques are operationalised. Instead, it is warranted to also describe the practical applications that are used in an intervention (e.g., by providing an intervention manual) and how the parameters for use are taken into account during intervention development (Crutzen, Peters, & Abraham, 2012; Peters, Abraham, & Crutzen, 2012).

Third, if BCPs are located on a continuum, the question 'how do BCPs (or BCTs or BCMs) rank in terms of effectiveness' is not a sensible question (e.g., Gardner, Smith, Lorencatto, Hamer, & Biddle, 2016; O'Brien et al., 2015). This effectiveness is a function of BCP, correct application of the BCP in terms of correct exploitation of the lower-level BCPs (and ultimately ELPs), match between BCP and determinant(s) targeted by that BCP, and the relevance of the targeted determinant(s) (Crutzen & Peters, 2017; Peters et al., 2015). Accepting that BCPs (or BCTs or BCMs) are not simply tricks that can be employed to directly influence behaviour (i.e., without affecting psychological

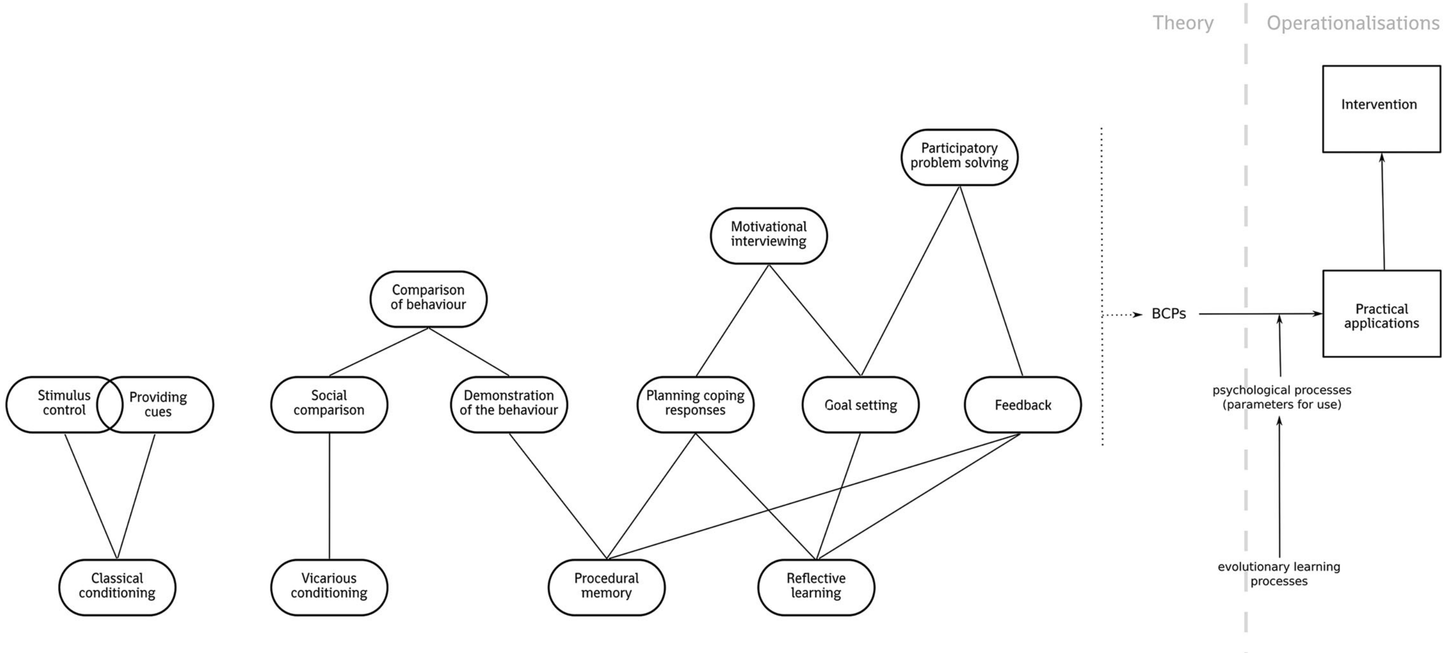

Figure 6. Combination of previous examples of BCPs, stressing the importance of adequate operationalisations.

processes) also means accepting that the conditions for their effectiveness are not so simple as to render questions such as 'how effective is this BCP' meaningful.

Final thoughts

Aunger and Curtis (2015) elaborate on the regularities in the niches in which organisms evolved resulting in distinct learning processes. Although their description of development of organisms over time is very convincing, this does not mean that the ELPs presented in Table 1 are necessarily comprehensive. We do think, however, that in order for a BCP to be effective, it has to rely on one or more ELPs. If future research sheds light on effective BCPs that do not rely on the ELPs presented here, then clearly, the ELPs presented in Table 1 are not comprehensive, and the list should be extended. To the best of our knowledge, however, these ELPs are comprehensive regarding the BCPs used in current interventions.

Although interventions are often aimed at behaviour change itself, this is only a first step for interventions to have a public health impact (Glasgow, Vogt, & Boles, 1999). Stimulating people to change their behaviour does not mean that they maintain this behaviour change over time (Kwasnicka, Dombrowski, White, & Sniehotta, 2016). An explanation for this phenomenon based on the reinforcement learning perspective used in this article is that most interventions might not be intensive enough to actually 'rewire our brain'. This intensity does not only refer to intensity of one session, but especially to intensity in the long run. From the presently introduced perspective, where ELPs are postulated as foundations in a continuum of BCPs, this can be explained at the ELP level of this continuum. For example, at the brain level, there is a trade-off between the speed of learning and its accuracy. If the rate of addition of excitases is increased beyond a critical point, the gradualism required for evolutionary learning is lost since the possibility for small changes in the excitase composition of neurons is lost (Kampfner & Conrad, 1983). This is also reflected at the behavioural level. Prevention of obesity, for example, is thought to be most successful when focusing on small changes in dietary intake and physical activity, since small changes are easier to maintain in the long run (Hill, 2009).

Conclusion

We have introduced a perspective where all BCTs and BCMs (more generally: BCPs) are placed on a continuum of aggregation. The ELPs form the foundation of this continuum. We discussed how this can be useful to select the appropriate BCPs to target determinants of behaviour and to identify and satisfy the conditions for their effectiveness. Using these insights during intervention development, in combination with a thorough understanding of ELPs, has the potential to increase the likelihood of developing effective interventions – both in terms of behaviour change as well as maintenance of behaviour change.

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