Design Science

Co-evolution in behavioural design: emergent synergy between behaviour change mechanisms and their embodiments

Pramod Khadilkar[1] and Philip Cash[2]

[1]*Department of Design, Indian Institute of Technology Delhi, India*
[2]*School of Design, Arts and Creative Industries, Northumbria University, UK*

Abstract

Behavioural design is an important, emerging area of research and practice. However, major questions remain regarding how behaviour change *mechanisms* should be *embodied* in artefacts to create effective *interventions.* Hence, we ask: *How do behaviour change mechanisms and their embodiments emerge and relate to each other during behavioural design processes*? We answer this question via analysis of 11, in-depth case studies of expert practice. Based on our findings, we reveal a complex, multi-layered co-evolutionary process in behavioural design, capturing development *within* and *between* spaces linked to behaviour change *mechanisms* and their *embodying* artefacts. Further, we relate the structure of this co-evolutionary development via *process synergy* between *mechanisms* and *embodiments* spaces to understanding and cohesion of the final *interventions.* This has significant implications for behavioural design theory and process guidance, as well as highlighting the need for further research on the link between design processes and interventions in this context.

Keywords: Behaviour change, Behavioural design, Co-evolution, Design theory, Design process

Received 16 September 2025 UTC
Revised 17 July 2026 UTC
Accepted 17 July 2026 UTC

Corresponding author
Philip Cash
philip.cash@northumbria.ac.uk

© The Author(s), 2026. Published by Cambridge University Press. This is an Open Access article, distributed under the terms of the Creative Commons Attribution licence (http://creativecommons.org/licenses/by/4.0), which permits unrestricted re-use, distribution and reproduction, provided the original article is properly cited.

Des. Sci., vol. 12, e26
journals.cambridge.org/dsj
DOI: 10.1017/dsj.2026.10070

1. Introduction

Behavioural design is an important, emerging area of research and practice, which has demonstrated significant results in fields ranging from well-being and health (Voorheis *et al.* 2022) to security and sustainability (Niedderer, Clune & Ludden 2017). These results are achieved via *interventions* that ethically shape positive behaviour change (Tromp & Hekkert 2014), developed through processes that combine aspects of design and behavioural science (Khadilkar & Cash 2020). However, while numerous process models have been proposed, current practice is replete with accounts of unexpected outcomes and tensions at the interface between design and behavioural concerns (Hagger & Weed 2019; Voorheis *et al.* 2022; Bay Brix Nielsen, Cash & Daalhuizen 2024). This points to an urgent need to better understand how *interventions* emerge from behavioural design processes.

In this context, behaviour change is realised through the development, delivery, maintenance and iteration of *interventions*, which *embody* behaviour change

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

mechanisms (Michie, Atkins & West 2015; Schmidt 2024). Here, *embodiments* are physical or digital artefacts that can range from individual interfaces, apps or products to whole services, systems or environments (Table 15.2 in Clune & Lockton 2017). In contrast, behaviour change *mechanisms* (henceforth, we will use the terms 'behaviour change mechanisms' and 'mechanisms' interchangeably, depending on the context of use) are conceptual behavioural principles that can vary in their underlying premises, scope and complexity (e.g., see discussion on strategies like eco-feedback or behavioural steering in Lilley 2009; theory informed behaviour change techniques in Michie *et al.* 2013; or use of dual system theory for behaviour change in Thaler & Sunstein 2008). The relationship between these two constructs is complex because *embodiments* can support multiple *mechanisms* and *mechanisms* can be translated into multiple *embodiments.* Therefore, their combination forms a central tenet of behavioural design processes (Cash *et al.* 2022). Yet this relationship also appears to be at the root of many of the challenges identified in current research and practice (Voorheis *et al.* 2022; Bay Brix Nielsen *et al.* 2024). This is despite recent advances in, for example, mapping of *mechanisms* and *embodiments* as part of Behaviour Change Intervention Ontology project (Michie *et al.* 2020). Thus, it remains unclear how the relationship between *embodiments* and *mechanisms* should be understood or fostered during the behavioural design process itself. Hence, we formulate the Research Question (RQ): *How do behaviour change mechanisms and their embodiments emerge and relate to each other during behavioural design processes*?

To answer this question, we analyse processes from 11 real-world projects through a co-evolutionary lens. Co-evolution provides a basic framework for capturing reciprocal influence between elements in a design process (Maher, Poon & Boulanger 1996; Crilly 2021). Therefore, we take the basic idea of co-evolutionary, reciprocal influence as a starting point for examining the interaction between behaviour change *mechanisms* and *embodiments.* Further, while co-evolution is generally associated with the thinking of designers (Smulders, Dorst & Reyman 2009), various authors have demonstrated its utility at a range of scales (Maher & Tang 2003; Wiltschnig, Christensen & Ball 2013; Crilly & Moroşanu Firth 2019). Hence, we use it to map task-to-task scale interactions across whole behavioural design processes. These two points of departure (reciprocal influence at the whole process scale) make co-evolution ideal for exploring our RQ and a foundation for theory development in this area.

2. Conceptual background

Before we can answer our RQ, it is necessary to understand what distinguishes behavioural design processes and how a co-evolutionary lens might be applied in this context.

2.1. Distinguishing behavioural design

Behavioural design can be distinguished from other design approaches by two main characteristics that emphasise the importance of its process. First, behavioural design processes are explicitly formulated with respect to behaviour change as the thing being designed (Khadilkar & Cash 2020). Here, designers aim to realise positive new situations by scaffolding the reduction, change in or adoption of new

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

behaviours via intermediary *interventions* (e.g., creating an app. to increase exercise behaviour to minimise the negative effects of a sedentary lifestyle). There is no fixed, *intervention*-related framing, start or end point. For example, to increase exercise behaviour, the *mechanism* of 'provide feedback' might be *embodied* in a pedometer, an app., a training programme or a mix of all three. Rather, development flexibly draws together behaviour change *mechanisms* and their *embodiments* to support the realisation of the new situation (Michie *et al.* 2015; Bay Brix Nielsen *et al.* 2024). Thus, while behavioural design projects can *posteriori* look like, for example, user experience or product design due to the *embodiments* used, this is not the case *a priori* or during the process.

Second, behavioural design processes bring two core values additional to typical design approaches: (i) grounding in behavioural theory and (ii) explicability. Here, designers integrate behavioural theory (of various sorts) and understanding of design. This creates a situation where it is insufficient to deliver an *intervention* that works within a general frame, as in most design approaches (e.g., approaches like human-centred design or product design do not demand use of specific theory as a basis for ideation; Roozenburg & Eekels 1995; Giacomin 2014; Human Centered Design Toolkit 2015). Behavioural designers must provide an explanation – grounded in theoretical and empirical insights – for the *mechanisms* and *embodiments* that make up *interventions* as well as how these have emerged from the design process (Taylor *et al.* 2006; Michie & West 2013). This then needs to be anchored by evidence for *intervention* effectiveness (at least in the short term) (Nielsen, Cash & Daalhuizen 2018; Cash *et al.* 2020).

Bringing these characteristics together, it becomes clear that while all types of design deal with the relationship between behaviour and artefact in some form, behavioural design reflects a distinct paradigm in the treatment of this relationship in its design process (Schmidt 2020).

2.2. Behavioural design processes

Behavioural design, as characterised in Section 2.1, faces the fundamental challenge that while *mechanisms* draw on behavioural theory, *embodiments* can be anything from user interfaces to media campaigns or policy, as well as combinations of these, and might also change over time (refer to Table 15.2 in Clune & Lockton 2017). Further, as noted in the introduction, the relationship between these two constructs is complex and interdependent. For example, multiple authors identify the prevalence of unexpected effects and uncertainty around the precise evidence for *mechanisms* and *embodiments* (Hagger *et al.* 2020; Cao, Cao & Sutherland 2025) as well as the need for iteration in context (Baxter *et al.* 2025). Hence, there is a need to manage both aspects and their interaction during behavioural design processes.

Yet multiple authors highlight the difficulties of effectively integrating the approaches needed to deal with both behavioural science-based *mechanisms* and design-based *embodiments*, due to differences in logic and thinking about iteration (Aunger & Curtis 2016; Schmidt 2020; Cash *et al.* 2022; Voorheis *et al.* 2022). Bay Brix Nielsen *et al.* (2024) explain how *mechanism*-focused approaches are typically characterised by deductive/inductive logic, where processes are more linear. In contrast, *embodiments*-focused approaches typically emphasise abductive logic where processes are more iterative. Current, dominant process models, such as

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

those from the OECD (2019) and Michie *et al.* (2015), respond to this through early concretisation of the problem definition as a basis for fitting behaviour change *mechanisms*, which can then be used to determine *embodiments* in a constrained design step (Lockton, Harrison & Stanton 2010; Bohlen *et al.* 2020). More generally, almost all current process models recognise some form of iteration. Yet how it is treated varies significantly, without a clear grounding in process theory. For example, iteration ranges from within stage, as in Aunger & Curtis (2016), to between stages, as in Fogg (2009, p. 6), to between whole projects, as suggested by the OECD (2019) and Michie *et al.* (2015). Hence, it remains unclear how the link between behaviour changes *mechanisms*, primarily rooted in behavioural science, and *embodiments*, primarily rooted in design, should be understood and managed. This points to an urgent need for focused investigation and theory development around the reciprocal influence between *mechanisms* and *embodiments* in behavioural design.

2.3. Co-evolution as a process lens

The dominant lens for describing reciprocal influence between two (or more) elements of a design process is co-evolution (Smulders *et al.* 2009; Dorst 2019; Crilly 2021). Co-evolution has been used to examine interactions between an array of different process-related concepts, including idea generation (Dorst & Cross 2001); analysis, synthesis and evaluation activities (Martinec *et al.* 2020); uncertainty perception (Cash, Gonçalves & Dorst 2023); and others (Wiltschnig *et al.* 2013). Further, while co-evolution typically refers to the interaction between problem space and solution space, Maher & Tang (2003) highlight how it can accommodate problem and solution spaces within 'two or more' conceptually different spaces, and Crilly & Moroşanu Firth (2019) specifically extend it to business-related spaces. Hence, co-evolution provides a flexible conceptual basis for examining reciprocal influence between different elements of the design process.

Co-evolution has also proven a useful lens for characterising design processes across a range of scales and contexts. For example, Martinec *et al.* (2020) used protocol analysis of specific design sessions in an experimental context, while Wiltschnig *et al.* (2013) also used protocol analysis, but from weekly meetings distributed over a duration of 5 months as a team developed a new product feature. At a larger scale again, Crilly & Moroşanu Firth (2019) compare co-evolution across whole projects using project milestones, documentation and interviews with the lead designer. Finally, Dorst (2019) compared co-evolution across multiple projects using secondary data and overall descriptions of problem-solution transitions. As such, the investigation of co-evolution has been operationalised in terms ranging from moment-by-moment shifts in individual attention in a specific design session to post-hoc characterisation of shifts in task-to-task focus during a team's design project. While this diversity of application can lead to ambiguity in what exactly is being captured by co-evolutionary descriptions (Cash *et al.* 2023), it can also lend a degree of continuity to the conceptualisation of a basic aspect of design, that is, reciprocal influence between elements in a design process (Crilly 2021). Hence, co-evolution offers the potential for connecting insights garnered from behavioural design processes with extant research on design processes more generally.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

2.4. Conceptual framework

Based on these theoretical foundations, we use co-evolution to explore how behaviour change *mechanisms* and their *embodiments* emerge and relate to each other during behavioural design processes. To do this, we decompose the overall design space as illustrated in Figure 1. Here, we operationalise the team-level focus of each task with respect to behaviour, that is, *mechanisms* or *embodiments* spaces, each of which is further sub-divided into *problem or solution* spaces, following a similar logic to Crilly & Moroşanu Firth (2019). Task-by-task progression within or across the *mechanisms*/*embodiments* spaces in Figure 1 can then be mapped across the behavioural design process. Here, the focus of a task is represented by a dot and the subsequent progression of the process to the next task by an arrow. To differentiate progression within *mechanisms* and *embodiments* spaces versus between these spaces, we refer to progression within a *mechanisms* or *embodiments* space as a 'move' (depicted by a straight arrow) and progression between *mechanisms* or *embodiments* spaces as a 'jump' (depicted by a curved arrow). This provides a basis for conceptualising progression based on the direct influence of one task on the next, following typical co-evolutionary logic (Dorst & Cross 2001). Further, it also provides a framework for distinguishing iteration in comparison to current literature (see Section 2.2). For example, the dominant logic of Michie *et al.*'s (2015) process is illustrated in Figure 1, where iteration is either implicitly treated within each space or at the level of the whole project. In Figure 1 and all subsequent process figures, moves and jumps progress over time and are 'stacked' vertically to aid readability. Hence, sequential arrows always depict progression over time, regardless of the arrow's direction (left to right or right to left).

3. Methodology

Given our RQ, we adopt a theory-building, multi-case study approach for three main reasons. First, co-evolutionary development in behavioural design has not been previously explored or theorised, creating a need for in-depth insight in this context (Colquitt & Zapata-Phelan 2007; Eisenhardt & Graebner 2007; Yin 2014). Second, behavioural design produces a range of *interventions* across a variety of application domains, and hence a multi-case approach is needed to distil underlying, cross-cutting insights (Yin 2014, p. 4). Third, case studies have formed the basis for prior work on co-evolutionary processes at the whole process scale (Crilly & Moroşanu Firth 2019), providing a reference point for our investigation. In this

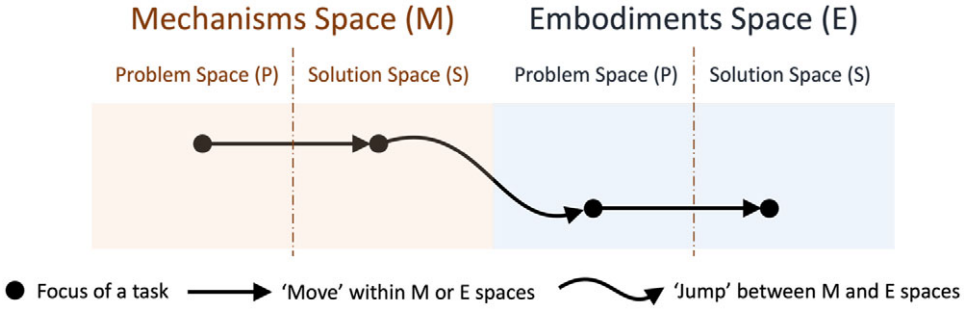


Figure 1. Basic conceptualisation of the behavioural design space through a co-evolutionary lens.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

approach, we focus on developing *analytical generalisability*, that is, abstraction of theoretical insights from the specific case data (Robson & McCartan 2011), and follow practices for qualitative case research (Gibbert, Ruigrok & Wicki 2008). This methodology is well suited to interdisciplinary challenges of design science where methods, tools and perspectives need to be aligned (Papalambros 2015).

3.1. Case selection

Cases were considered at the project level and were selected based on two theoretical and one practical criteria to ensure methodological rigour (Yin 2014). First, the project must have an active or overt aim of changing behaviour and be explicitly recognised as behavioural design by the participants (Tromp, Hekkert & Verbeek 2011; Niedderer *et al.* 2017). This was based on the features of behavioural design processes and their intended outcomes, irrespective of the specific *interventions* delivered at project completion (see Section 2.1). Second, the project should cover a complete expert-led design process, that is, from the overall aim to testing (Cash, Hartlev & Durazo 2017). This was based on our scale of investigation and allowed for a maturation of the relationship between behaviour change *mechanisms* and *embodiments* (see Section 2.4). Third, there should be good data access to critical decision-makers, such as project managers, designers and behavioural analysts, as well as supporting secondary data sufficient to establish and then triangulate (Yin 2014) team-level progression in task-to-task focus across a whole design process.

To understand expert practice, all cases were drawn from successful behavioural design consultancies with more than 5 years of experience in Denmark. These consultancies specialised in behavioural design and constituted leaders in their field nationally, while Denmark is generally considered an international leader in this area. As such, the sample of companies can be considered to provide insight into leading, expert practice within a mature context.

The consultancies were requested to provide a list of possible projects that they considered behavioural design, along with a brief description of the process, aims and outcomes. This allowed for a nested approach to case selection to build external validity (Gibbert *et al.* 2008). We selected 11 project cases from the four companies operating during 2018–2020 when the interviews were conducted, hence allowing for concurrent and retrospective data collection across our sample. The selected cases reflected varied behavioural problems (Michie *et al.* 2015) as they spread across application domains, commercial focus and company context. Further, *interventions* ranged from systems of products to individual products or other *embodiments*, and in application areas ranging from health to safety. In all 11 cases, designers dealt with multiple behaviours. This diversity helped us in extracting cross-cutting insights and hence supported our analytical generalisation approach (Robson & McCartan 2011). Overall, four projects focused on the social context dealing with behaviours in public places, like airports; two focussed on industrial contexts that dealt with behaviours in private professional organisations; two focussed on personal contexts relating to behaviours in private settings, and three cases had multiple contexts. Finally, 10 out of 11 cases were initiated with at least one evident problematic behaviour or target behaviour linked to the context in which the behaviour was happening. An overview of cases is provided in Table 1.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Table 1. Overview of cases

Case	Project type	Team/participants (*)	Domain/context	Deliverables and evaluation
Company 1: Consultancy in business management and design				
1	Design of online expense system and user interface	Project lead*; designer*; IT engineer*	Industrial context – private professional organisations	Online form, informational materials, communication approach; A/B testing
2	Design of online job-logging system and user interface	Project lead B*; designer A*	Social context – behaviours in public places	Online form, informational materials, communication approach; A/B testing
Company 2: Consultancy in technology development				
3	Design of artefact and system for taking medication	Project lead/designer*; designer*; IT engineers 1 & 2	Social context – public places (Old age homes)	Intelligent pillbox, monitoring system; initial testing and expert feedback
4	Design of artefact and system for children saving	Project lead/designer*; designer*; IT engineer	Personal contexts – behaviours in private settings	Intelligent piggybank, with bank system; initial testing and expert feedback
5	Design of artefact and system for patient training	Manager*; project lead/designer*; designer C; IT engineer	Social context – behaviours in public places	Belt with sensors, monitoring system; initial testing and feedback
Company 3: Consultancy specialising in behaviour change				
6	Design of communications for online safety	Project manager/ designer*; survey designer*; research assistant	Mixed (social/ personal) – behaviours in private as well as social settings	Informational materials (printed and electronic); pre/post survey and implementation data
7	Design of artefact and system to support home CO2 management	Project manager/ designer*; designer*	Personal contexts – behaviours in private settings	CO2 measurement service, email feedback, CO2 lamps, habit guide; tested versus baseline
8	Design of artefacts and social system to support home safety	Project manager/ designer*; designer*; product engineer; research assistant	Mixed (social/ personal) – behaviours in private as well as social settings	'Safety kit' including informational materials and assessment tools; implementation and follow-up
9	Design of space, signage and wayfinding in train stations	Project lead/designer*; designer*; survey designer; research assistant	Social context – behaviours in public places	Physical signage and environment design; tested versus baseline

Continued

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Table 1. Continued

Case	Project type	Team/participants (*)	Domain/context	Deliverables and evaluation
Company 4: Consultancy featuring a specialised behaviour change division				
10	Design of safety monitoring and support system	Project lead/designer*; designer*; 3 research assistants	Industrial context – behaviours in private professional organisations	Training programme, materials, work protocols, digital product; implementation and follow-up
11	Design of a digital IT system	Project lead/designer*; change lead*; 3 in co-team	Mixed (social/industrial) – behaviours in social as well as industrial settings	Training on behaviour change, behaviour change process; model only

3.2. Data collection

Within each case, we followed Crilly & Moroșanu Firth (2019) in drawing data from multiple, concurrent and retrospective sources, including project milestones, documentation and interviews with the main designers in each project. This allowed for data saturation and triangulation both within and across cases (Yin 2014, pp. 56–61). Primary data were collected in the form of 24 semi-structured interviews and observations in the case companies.

A semi-structured interview guide based on our conceptual framework was used to conduct the interviews and ensure the internal validity of our collected data (Gibbert *et al.* 2008). Interview questions dealt with three main topics: (i) the behaviour being addressed, (ii) the outcomes of the design process and (iii) the design process itself. The questions related to each topic are outlined in Table 2. Follow-up questions and elaboration were used to ensure the elements of our conceptual framework were fully explored across the whole design process in each case.

The first author conducted face-to-face interviews with the key decision-makers in each project team. All the interviews were audio recorded with the prior consent of the participants. The interviews lasted for approximately 1 hour. Each case had multiple interviewees, with the aim of reaching saturation (Guest, Bunce & Johnson 2006), that is, further questioning did not reveal any new information. Due to the small size of the involved teams (typically only two or three designers/analysts), in most cases, the whole team was interviewed. After explaining the involved behaviours and resultant *interventions*, each interviewee was asked to elaborate on the design process using process diagrams and sketches. During the interviews, these process diagrams worked as a reference to discuss the process-related aspects and link this back to the *mechanisms* and *embodiments*. Secondary data were collected via internal reports, project briefs, presentation decks, final project reports, blogs and so forth. This allowed us to map the progression across spaces (Figure 1) during the whole process in each case based on triangulation of concurrent and retrospective data from multiple sources.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Table 2. Sample interview questions

Topic	Example questions
Behaviour being addressed	Can you talk me through the behaviour you worked on in this project? What were its characteristics and range of behaviour? How general was the behaviour and demographic? What were the causes of this behaviour? Why do you think users behave in this way? How did you arrive at the target behaviour?
Outcomes	How did the intervention get the person from current behaviour to target behaviour? What other interventions did you consider during development? How did you evaluate the success of the project?
Design process	How did these considerations [related to behaviours] inform your project formulation? Did you make a brief, if so what did it include? Can you sketch a project timeline and talk me through the process from idea to final solution? Do you differentiate projects with respect to the target behaviour? If so, how? How did you set up the project and team organisation? How did you keep track of the project? How did you evaluate your ideas during the design process? Can you talk me through the major iterations in the project process?

3.3. Data analysis

Transcriptions of the audio recordings were used as the basis for thematic analysis, supplemented by the secondary data. First, open coding was used to understand the overall behavioural design process undertaken in each case. This covered both the practical details and the conceptual aspects, such as the nature of the behavioural design problem and reasoning of the design team (Neuman 2011, p. 511). This was also used to check that the processes aligned with the criteria for behavioural design, irrespective of the *interventions* being developed, as discussed in Section 2.1. At this point, initial findings were presented back to the design lead for each case in the form of verbal data summaries and initial process sketches. This served to confirm our basic interpretation of each case, the accuracy of process characterisation, and the overall assessment of the project and its outcomes. As we had worked closely with all companies before data collection, we were well positioned to interpret the interview data; hence, no major challenges emerged at this point. This helped to increase the validity of our basic findings as a foundation for theory development (Miles, Huberman & Saldaña 2014, ch. 11).

Second, with the veracity of our characterisations validated, we then conducted iterative axial coding, where cases were contrasted to develop abstract, cross-cutting themes (Neuman 2011, pp. 512–513). The authors ensured conceptual

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

validity by moving between the data and the literature in an iterative process (Miles *et al.* 2014, ch. 4). We then used temporal bracketing to divide the continuous overview of the cases into multiple discrete periods so that we could trace progression within and between spaces (Langley 1999). For each case, we developed process maps to help visualise progression and form a basis for refining our insights in process terms. Here, we identified co-evolutionary influences by identifying specific descriptions of problems and solutions and their progression in the timeline using quotes as well as secondary documents and the process maps, for example, the Designer in Case 1 stated that: '*it was not initiated from a behavioural perspective*'. The description of the problems and solutions was sufficient to assign them to either to *mechanisms* space or to *embodiments* space, for example, the Designer in Case 1 stated that: '*then we used some UX …when we made the new* [intervention], *which was a web-based form*'. However, we also identified when and how *mechanisms* influenced *embodiments* and vice versa, for example, the Lead Designer in Case 7 stated that: '*we ended up with these four* [interventions], *"information*, [and] *habit" from the pilot; and then "nudging and feedback", because that was feasible*'. This resulted in the identification of co-evolutionary progressions within and between *mechanisms* and *embodiments* spaces, following the logic outlined in Figure 1.

Finally, we compared our findings with prior co-evolutionary studies and theorising to draw out the distinctive nuances of the themes emerging from our data (Langley 1999). We aimed to extract theoretically relevant patterns from across cases, and hence mitigate the impact of variation and possible confounds associated with the individual cases themselves. Specifically, this analysis step allowed us to check for and eliminate the possibility of confounding process patterns at the company or project level linked to project teams or constraints. Here, all companies showed variations in the level of temporal and budgetary constraint, with no clear patterns emerging in relation to our extracted themes. Hence, while further research is needed to examine contextual interactions with project processes and outcomes, for the purposes of this research, they were not analytically significant. This process concluded when we reach analytical saturation, that is, the iterative comparison of cases did not reveal new co-evolutionary patterns and results served only to further detail first-order findings associated with already established themes (Miles *et al.* 2014, ch. 4).

4. Findings

Considering our cases at the most basic level, we found that all cases followed typical behavioural design steps in identifying a problematic behaviour and then working towards its resolution based on a combination of empirical and theoretical insights. A typical set of steps was: (i) identification and definition of the initial problematic behaviour or need; (ii) analysis and mapping of the problematic behaviour; (iii) development of a problem/target behaviour specification; (iv) identification of behaviour change *mechanisms* and proposal of *embodiments*; (v) iterative testing and development of prototype *embodiments* to identify barriers and effects; and (vi) communication and launch. This sequence of steps was reflected in our concurrent observations and discussions with design teams, as well as in secondary data and retrospective process sketches developed in the interviews. For example, the Project Manager and Designer for Case 7 stated: '*it*

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

consists of every part of the behavioural design process… it has desk research… expert interview. It has investigations into people's perception of the problem. It has intervention design, test of intervention design, second round of intervention design based on the pilot of the first round experiences, and then a larger randomized control trial'. Similarly, the Lead Designer for Case 1 stated that: '*we did the project proposal* [where] *we had already laid out the method for the research… then we did interviews. I also did a behavioural assessment of all the information and a process mapping*'. Further, secondary data revealed how two of the case companies employed an explicit 'process template' across projects, and presentation slide decks used in multiple cases included overviews of process steps as well as references to behavioural and behavioural design research.

While not revealing new insights, these data provide important confirmation of our research framing. Specifically, they confirm the behavioural design nature of our cases (Section 2.1), following identified precepts of behavioural design (Michie *et al.* 2015; Khadilkar & Cash 2020; Schmidt 2020), as well as process steps and methods (Aunger & Curtis 2016; Cash *et al.* 2017; Voorheis *et al.* 2022). Further, all cases displayed two-way interactions between behaviour change *mechanisms* and their *embodiments.* Thus, these data provide a solid basis for further theory development in the behavioural design context.

4.1. Non-linear development of behaviour change mechanisms and their embodiments

The first theme to emerge was iteration between design of the behaviour change *mechanisms* and their associated *embodiments.*

Unsurprisingly, the *mechanisms* formed the primary focus of the design work and were associated with steps dealing with the specifics of the behavioural problem and its cognitive or behavioural solution. This is illustrated by Lead Designer in Case 11: '*everything that we do for designing interventions has to be with an understanding of, how this one person is functioning? what drives this person's behaviour? what's this person's logic?*'. Steps dealing with the behavioural problem were concerned with understanding and mapping the cognitive and behavioural *mechanisms* involved in the behaviour. For example, the Project Manager and Designer in Case 7 elaborated the behavioural nature of the design problem as: '*we identified eight themes for why this behaviour* [the target behaviour] *wasn't taking place. One is that, people don't perceive it to be a problem*, [the cause of the problem] *is still abstract*'. Similarly, steps dealing with behavioural solutions focused on the identification and integration of generic cognitive or behaviour change *mechanisms*, such as feedback, priming or reducing cognitive load. The Lead Designer in Case 1 explained a possible behavioural solution as: '*Making the user think as little as possible, not make them understand rationally what you have to do* [but] *just intuitively see what you have to search*'. In all cases, multiple *mechanisms* were proposed and combined in the final solutions.

However, the design of the *mechanisms* did not progress linearly, to then be 'frozen' and used as a basis for *embodiment* selection, as is typically suggested in current, behavioural design process models (Section 2.2). Rather, we found that much of the design of the *mechanisms* was guided by the design of the *embodiments.* This is illustrated by the Lead Designer in Case 3: '*So you took the old behaviour into the new digital product, we also proposed that you could* [achieve a

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

desired behaviour] *by* [an additional feature on new product]'. Here, the design team responded to insights directly associated with the *embodiment* and associated implications for implementation of the solutions (e.g., through products, systems and other means). This included identification of additional *mechanisms* as well as fine-tuning, modification or removal of initial *mechanisms.* Hence, the designers were prompted to revisit the *mechanisms* space in relation to the *embodiments* space. The Project Manager and Designer in Case 7 stated: '*This was a habit-forming intervention based on the psychology around implementation intentions. Participants were sent an information leaflet on the intervention and then they were given a sticker and a small schedule that they had to fill out*'. In this case, the designer was not only thinking about the initial *intervention* and associated behaviour change but also ongoing continuation of behaviour via habit formation. Overall, there was a consistent pattern where the design team worked through two distinct areas within the *mechanisms* space: one related to the initial *mechanisms* and the other related to the *mechanisms* revealed by or made necessary for the success of the *embodiments, that is, embodiments*-related *mechanisms.* In the earlier example of a pedometer, it must be accepted/purchased, properly used/charged/upgraded and carefully discarded. These are linked with the characteristics of the *embodiment* and introduce *embodiments*-related *mechanisms.* These are influenced by the functions, aesthetics, colour, finish and ergonomics of the *embodiment*, as well as aspects of behavioural theory. For example, technology acceptance theory is associated with acceptance of technology and is based on the 'Theory of planned behaviour' (Ajzen 2005), while diffusion theory introduces multiple factors, such as perceived criticality of need or complexity (Rogers 1983), all of which are behavioural in nature.

The interaction between the spaces is further reflected by secondary case data, with multiple cases generating three distinct sets of specifications related to: (i) the initial *mechanisms* via a behavioural specification, (ii) the *embodiments* via a technical specification of the *intervention* and (iii) the *embodiments*-related *mechanisms* via a revised overall specification. This led to significant non-linearity in the observed cases, with jumps between the *embodiments* space and the *mechanisms* space in both directions; with this latter space having a clear distinction between the initial *mechanisms* and the *embodiments*-related *mechanisms.* For example, the Project Manager and Designer in Case 7 reflected on how they had to update the *mechanisms* in light of *embodiment* considerations: '[in] *the* [intervention] *we have an SMS component that people said, it was really good idea, but nobody actually used that system. So we found out that we needed to do something else with it*'. This is exemplified by the process in Case 7, as illustrated in Figure 2b. Here, the *mechanisms* are established, an initial *embodiment* is proposed, the *mechanisms* are revisited considering this *embodiment* proposal and then a final *embodiment* is delivered. Similarly, Case 1 began with an existing *embodiment*, prompting an immediate shift in focus to the relevant *mechanisms.* This triggered the development of a new *embodiment*, which, in turn, prompted an iteration of the *mechanisms*, followed by finalisation of the *embodiment*, as shown in Figure 2a.

While prior work has identified the need for both *mechanism* and *embodiment* development, the dominant framing in the literature is linear and *mechanisms* focused (e.g., the eight-stage process by Michie *et al.* 2015; see Section 2.2). Current process models suggest developing and 'freezing' the *mechanisms* before *embodiment* selection and/or development (Michie *et al.* 2015). Here, the need for

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

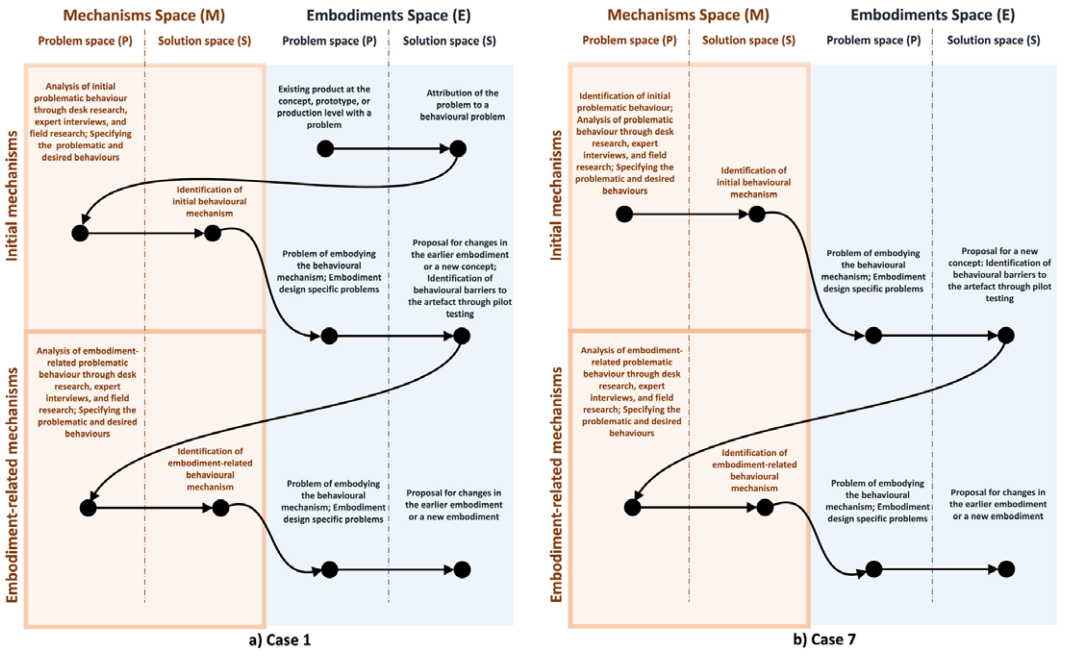


Figure 2. Distinction between mechanism and embodiment-focused tasks in (a) Case 1 and (b) Case 7.

iteration is sometimes included within stages, but not typically across stages. Hence, current process descriptions either exclude or limit the potential for jumps between the *mechanisms* and *embodiments* spaces, depicting linearity. Yet our results suggest that the expert process breaks this linearity. Specifically, *embodiment* design provides inputs that result in the addition and/or modification of the initial *mechanisms*, leading to multiple additional jumps from *mechanisms* to *embodiments* to *embodiments*-related *mechanisms* and so on. Critically, it was these jumps that allowed the observed teams to deliver solutions that leveraged both spaces, and incorporated both design and behavioural science insights. However, while this emphasises the need to reconsider typical assumptions about the linearity of behavioural design processes, it falls short of explaining how non-linearity should be understood in this context.

4.2. Co-evolution of behaviour change mechanisms and their embodiments

To understand the observed non-linearity outlined in the prior section, our second theme elucidates a complex set of co-evolutionary relationships underpinning the behavioural design process. Here, we found that our observed cases involved three interconnected yet distinct, co-evolutionary processes: (i) co-evolution within the *mechanisms* space, (ii) co-evolution within the *embodiments* space and (iii) co-evolution at a higher level between spaces.

Comparing processes across the cases revealed that there was cross-cutting interaction based on co-evolutionary developments in *mechanisms* space triggering development in the *embodiments*-related *mechanisms* space and vice versa. We

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

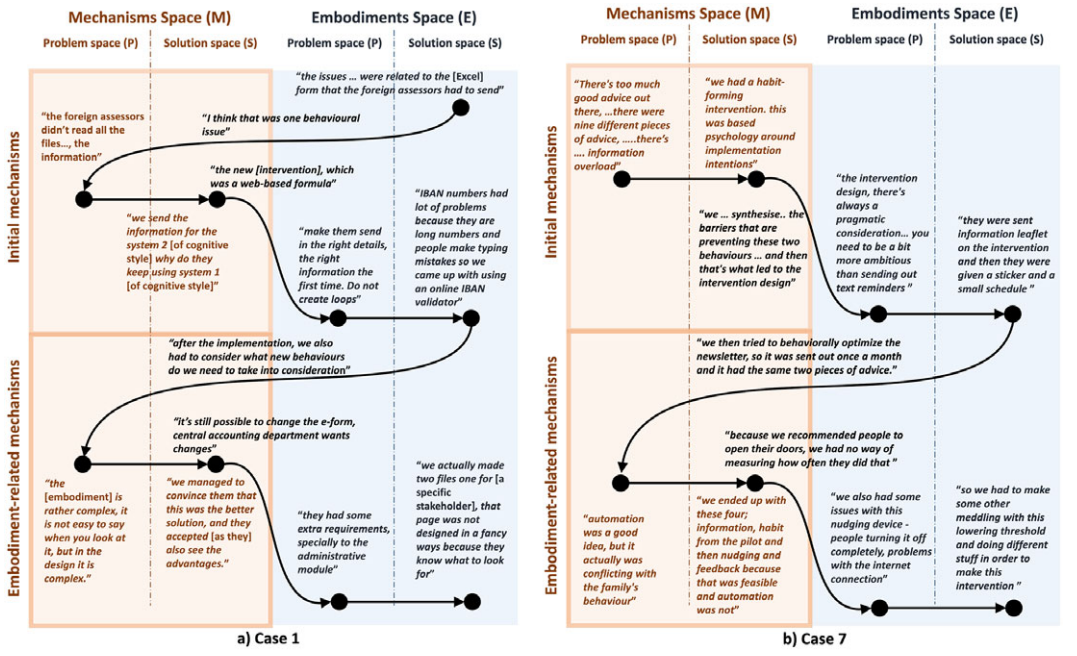


Figure 3. Co-evolution between mechanisms and embodiments in (a) Case 1 and (b) Case 7.

denote this in Figure 3 by differentiating the development of the *embodiment* in relation to the initial *mechanisms* from the start of the project and the *embodiments*-related *mechanisms* derived in response to initial *embodiment* prototypes or test implementations. The Project Manager and Lead Designer in Case 7 highlighted this bridge between the *mechanisms* and *embodiments* spaces: '*we had a behavioural barrier mapping* [mechanisms problem]… *and then that's what led to the intervention design* [embodiment solution], *and in the intervention design, it's worth saying, there's always a pragmatic consideration when you create interventions* [embodiment problem]' (see Figure 3b). Conversely, the Lead Designer in Case 3 highlighted how development of the *embodiments* triggered new understanding of *mechanisms*: '*asking the people that are actually supposed to use it* [embodiment concept] *in practice* [embodiment solution] *actually made us realize that this will never work* [in terms of behaviour; mechanisms problem]'. Similarly, the introduction of *embodiments* also changes the original behaviour, which impacts the *mechanisms* space; as explained by the Lead Designer in Case 1: '*after the implementation* [of an *embodiment* solution] *we also had to consider what new behaviours do we need to take into consideration for the users* [*mechanism* problem]' (see Figure 3a). Co-evolution was further illustrated by the Project Manager and Lead Designer in Case 9 as: '*you jump back and forth many, many times, because you learn things and you figure out, this barrier to the behaviour is really big, maybe we can develop a solution to it. "No we can't, because it costs a lot of money" and you have to walk back and forth'*. Thus, co-evolution within each space (*mechanisms* and *embodiments*) is also shaped by co-evolution between them.

Figure 3 provides two examples of how this nested co-evolutionary process progressed, with illustrative data and quotes from Cases 1 and 7. Here, the

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

co-evolutionary framing highlights an important distinction between Case 1 (Figure 3a) and Case 7 (Figure 3b). In Figure 3, the dark orange quotes are related to the *mechanisms* space, the dark blue quotes are related to the *embodiments* space and the black quotes are related to the need for jumping between the spaces. Specifically, Case 7 started with a behavioural problem independent of any existing *embodiments*, driving the development of multiple new *embodiments* solutions, which subsequently produced an array of new behaviours resulting in further evolution of the *mechanisms* space. In contrast, Case 1 started with a specific problem related to an existing *embodiment*. This was then traced to several behaviours independent of the *embodiment*, resulting in the proposition of a totally new *embodiment* solution better matching the identified *mechanisms* problem. In both cases, co-evolution within the *mechanisms* or *embodiments* spaces prompted major re-frames in the other space, which helps explain how a single behavioural design process can trigger the development of multiple *embodiments*, as in Case 7. However, this posed specific and significant challenges to the design teams, as explained by the Lead Designer in Case 7: '*the behavioural component in your intervention targets the barriers that you identified. Once we have the skeleton around a concept we can prototype that, but it's really hard to leap from, "here's a* [behavioural] *problem* [and] *here's a way* [an embodiment] *that we can actually solve it!"*'. Thus, the multiple interacting co-evolutionary processes help us to capture how *mechanisms* and *embodiments* mutually influence each other.

While prior work has suggested that iteration might be an important avenue of investigation for the refinement of behavioural design processes (Schmidt 2020; Bay Brix Nielsen *et al.* 2024), what form this might take has remained ambiguous. Our results decompose these iteration issues and demonstrate why it is important to not only iterate within individual spaces (as is currently the case in most behavioural design literature (Cash *et al.* 2017; Bay Brix Nielsen *et al.* 2024)) but also to facilitate iteration between them. Specifically, the *mechanisms* succeed – or fail – through their *embodiment*, and *embodiments* succeed only if the *embodiments*-related *mechanisms* ensure that the *intervention* is successfully accepted, used, maintained/serviced and discarded (see Figure 3). The Project Lead and Lead Designer in Case 5 highlighted this as: '*if a company comes to us… what they're looking for is not necessarily the product, but the results that the product will give them, and I think having this structure of a behavioural design approach, heightens the chance of that happening… I know that the first thing you do is do the technical approach… instead of looking at what is the problem actually… so let's look at the design outcome and design behaviour*'. Critically, our results illustrate how expert behavioural designers foster co-evolutionary alignment between *mechanisms* and *embodiments* spaces to create satisfying pairings of problem and solution spaces at the overall *intervention* level. This significantly recontextualises the discussion of behavioural design processes as it concretises the process-based linkages between *mechanisms* and *embodiments*.

4.3. Co-evolution and emergent synergy

Finally, relating our findings back to our RQ and building on our second theme, our third theme illustrates how co-evolution contributes to the development of *process synergy* between *mechanisms* and their *embodiments*. Here, we operationalise

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

process synergy as the extent of linkage between spaces. This is primarily based on: (i) the overall number of jumps between spaces, (ii) the number of jumps specifically from *embodiments* to *mechanisms* space, depicting updating of the *mechanisms* space in relation to insights associated with the *embodiment* and its implementation, and (iii) the number of jumps specifically from *embodiments*-related *mechanisms* to *embodiments* space, depicting the degree to which updated *mechanisms* are brought back into the *embodiments*. All of these jumps reflect deviations from the prevailing notion of linearity, with a single jump from *mechanisms* to *embodiments* space (Figure 1). Importantly, *process synergy* reflects the degree of alignment between *mechanisms* and *embodiments* in the design process, with the assumption that greater alignment will lead to better outcomes in the long term because possible confounding effects from one space or the other can be accounted for in the final *intervention*. However, this link between process and outcomes cannot be established concretely in our data and rests on the widely accepted logic of the need for alignment between spaces found in the broader literature (Dorst & Cross 2001; Crilly 2021). Hence, we conceptualise *process synergy* as an explicitly process-related success construct at this stage.

While some *process synergy* was observed in all cases, contrasts here revealed several additional insights towards its extent. Specifically, Cases 2, 3, 5, 6, 7, 8 and 9, in Figure 4a, started with a problem not associated with any specific *embodiment*, while Cases 1, 4, 10 and 11, in Figure 4b, started with a specific *embodiment*, which was then translated into the *mechanisms* space. Decomposing the behaviour-initiated projects (Figure 4a), Cases 3, 5 and 7 highlight at least 2 jumps between *mechanisms* and *embodiments*, and 1 jump between *embodiments*-related *mechanisms* and the *embodiments* (for 3 total, as in Figure 4a), supporting strong

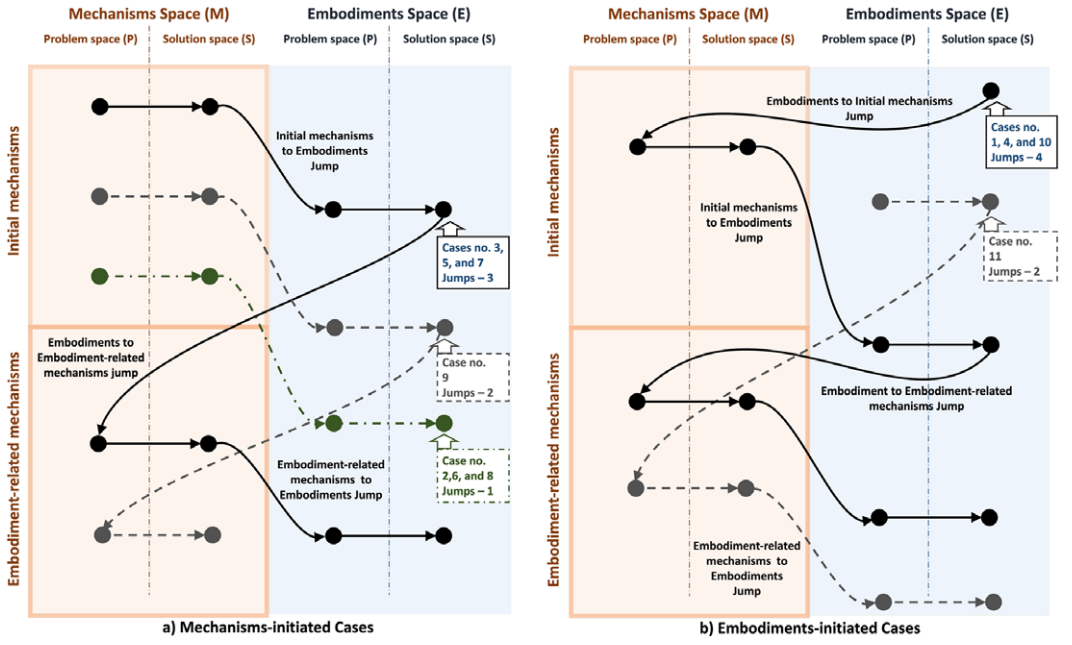


Figure 4. (a) Group 1 – Mechanisms-initiated projects, (b) Group 2 – Embodiments-initiated projects.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

alignment between the spaces in the final *intervention*. The Project Lead and Designer of Case 5 discussed the outcomes of the project as: '*we did this context study and from that we created prototypes*, [then we did] *ideation again, and then prototypes and testing. The major reason for not being successful lay in the motivation for using it… these workshops with the patients… changed our perspective*'.

In contrast, Cases 2, 6 and 8 had just one jump between *mechanisms* and *embodiments*. The cases had no reported (*embodiments* to *mechanisms*) jumps as they were more open-ended, with *interventions* comprising multiple elements, including educational and social components, for which iteration was less feasible within the project's constraints. The reasons for the limited iteration in Case 2 were elaborated by the Project Lead as: '[it is] *all part of being a consultant, you come up with what you think is great idea! and then the client says, "Oh thanks! thanks a lot, we'll do it ourselves or something, that's just life"*'. Here, instead of continued development, there was typically a plan in place for subsequent co-evolutionary refinement via post-project monitoring and iteration depending on the observed *embodiments*-related *mechanisms*.

A similar pattern was observed in the *embodiments*-initiated projects (Figure 4b). Here, Cases 1, 4 and 10 involved 4 jumps between *mechanisms* and *embodiment*, as well as at least one jump between *embodiments*-related *mechanisms* and *embodiments*. The Lead Designer of Case 10 elaborated how the project resulted in multiple *interventions*: '*we went through everything* [behavioural data] *and we found that the* [current embodiment] *was…* [communicated using language inappropriate to the audience] *so communications changed* [Intervention 01]. *We then tried to decrease the current* [problematic] *behaviour, minimise it by making it difficult* [Intervention 02], *and then we focused on driving the behaviour in very small steps, so instead of introducing the entire system we introduced one critical part, so we worked a lot with feedback loops* [Intervention 03]'. Here, the secondary data show that the design team went through at least six different jumps between *embodiments*-related *mechanisms* and *embodiments*.

However, exceptions to this pattern were observed in Cases 9 (Figure 4a) and 11 (Figure 4b), where only two jumps between *mechanisms* and *embodiments* occurred. Here, Case 11 co-evolved only in terms of the *embodiments*-related *mechanisms* and *embodiments*. Interestingly, both Case 9 and 11 involved complex systems and multiple *mechanisms* across a large set of people. Lead Designer in Case 11 elaborated the significance of this on the project as: '*after we had done our insights study, because there were a lot of behaviours, we believed we didn't have budget to solve all of it… with a lot of things that we hadn't thought about with the* [main project of which this project was a sub-project], *and a lot of things that* [client] *hadn't thought about as they decided on this very vague description of an* [overall *embodiment* system as the starting point for the project] *that would solve their issues*'. These issues resulted in fewer co-evolutionary moves and jumps, resulting in lower *process synergy*.

By contrasting results across cases, it becomes clear that the extent of co-evolution within and between spaces contributed *process synergy*, which could broadly be linked to perceptions of better understanding and formulation of final *interventions* by the design team. Cases 1, 3, 4, 5, 7 and 10 all have significant iteration, dependent on the designers' understanding of the multiple barriers to the *mechanisms* and the proposed *mechanism* solutions. Here, co-evolutionary jumps between *mechanisms* and *embodiments* both helped improve initial ideas and

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

developed newer, different ideas. The Lead Designer in Case 3 highlighted this as: '*All of the times that we have decided, we need to discard that completely and start over… the* [embodiment] *had to change because we incorporated the behavioural practice of the* [stakeholder]. *We got insights on their practice that says, "minor detail, this will never happen, so you need to do this instead"*'. In addition, *process synergy* was also linked to refinement of the *embodiments*, with multiple cases in Figure 4 iterating their *embodiments* with respect to insights from testing and subsequent updating of requirements derived from *embodiments*-related *mechanisms*. Further, where this was not possible within the constraints of the project timeline, the extent of co-evolution was typically planned for the post-project context. In large part, this reflects the expertise of the consultancies in dealing with factors outside their control associated with the *embodiments* and their implementation, and hence planning how to account for *embodiments*-related *mechanisms* via post-project monitoring and adjustment, that is, aiming to develop *process synergy* even after project completion. Hence, *process synergy* contributed to the refinement of understanding in both *mechanisms* and *embodiments* spaces as well as alignment between them, with logical implications for the overall coherence of the final *intervention*.

These results strongly emphasise the importance of reciprocal reframing between the *mechanisms* and *embodiments* spaces, as well as the significance of substantive iteration between and within stages of the behavioural design process. Critically, the effects of initially identified *mechanisms* could only be fully understood once *embodied*, and hence iterative refinement of *embodiments*-related *mechanisms* was essential to delivery of the final *intervention*. This contrasts with the de-prioritisation of *embodiment* as a finishing step with limited recourse for iteration of *mechanisms*, as depicted by, for example, the behaviour change wheel (Michie *et al.* 2015). This was reflected by repositioning of *embodiment* within the behavioural design process to account for jumps between spaces and iteration in light of *embodiments*-related *mechanisms*. This significantly extends current behavioural design thinking in that it elucidates the contrast between effective, expert practice and current process prescriptions. Specifically, most current process models forward a selection-based approach to identifying *mechanisms*, which then determine the selection of *embodiments* (Bhamra, Lilley & Tang 2011; Michie *et al.* 2015). Yet our results highlight how this relationship should be understood as reciprocal, with *mechanisms* and *embodiments* exerting mutual influence on each other. Therefore, this relationship cannot be resolved via linear steps but rather requires iteration to gradually align the interacting spaces from Figure 1.

5. Discussion

In contrasting the processes observed in our 11 cases, we identified several notable features that significantly advance understanding of the behavioural design process. First, we characterise co-evolutionary development *within* both the *mechanisms* and *embodiments* spaces. This significantly elaborates prior research, which typically focuses on development in the *mechanisms* space and leaves *embodiment* largely implicit (Lockton *et al.* 2010; Michie *et al.* 2013).

Second, we identify co-evolutionary development *between* the *mechanisms* and *embodiments* spaces, with the emergence of *embodiments*-related *mechanisms* as an important consideration. This contrasts with the dominant view in current

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

behavioural design research and prescription, suggesting a more linear and direct transition from *mechanisms* to *embodiments* spaces (Datta & Mullainathan 2014; Michie *et al.* 2015).

Third, we identify *process synergy*: the extent of co-evolution between *mechanisms* and *embodiments* spaces, as an important factor shaping understanding and coherence of the final *intervention*. In our results, projects with greater *process synergy* (i.e., multiple jumps between *mechanisms* and *embodiments* spaces) achieved greater alignment between behavioural and artefact-related considerations and were better able to account for *embodiment* and implementation-related factors in the final *intervention*.

Figure 5 illustrates these findings and serves as a point of comparison to our initial conceptual framework (Section 2.4) as well as typical descriptions of influence between *mechanisms* and *embodiments* in current behavioural design processes prescriptions. Hence, the recognition of co-evolution at multiple levels in behavioural design, as well as its salience in fostering *process synergy* constitutes important advances in this context.

5.1. Implications for behavioural design

The understanding illustrated in Figure 5 provides the basis for two major implications for behavioural design process prescriptions (Section 2). First, current process research and prescriptions in behavioural design provide essential steps but do not typically explain how to manage the iterative interaction between behaviour change *mechanisms* and *embodiments* (Section 2.1). Our results highlight how expert practitioners enable iterative, reciprocal influence both between *mechanisms* and *embodiments* spaces as well as within each space (Figure 5). Within spaces, this allows them to align and iterate on specific aspects of the design task, for example, by ensuring that their selection of behaviour change *mechanisms* aligns with their developing understanding of the *mechanisms* space or – in the *embodiments* space – by aligning their selection of technology with that found feasible, viable and desirable by the involved stakeholders. Between spaces, reciprocal influence is an essential driver of refinement and alignment, ensuring that behaviour change *mechanisms* are appropriate not only to the core behavioural problem but also to any aspects introduced by the *embodiments*, that is, *embodiments*-related *mechanisms*. Jumps between initial *mechanisms*, *embodiments* and *embodiments*-related *mechanisms* together support delivery of a cohesive *intervention*. This challenges prior understanding, where such iteration and alignment is typically not discussed, the process is formulated as largely linear (Francis *et al.* 2009; Bhamra *et al.* 2011; Michie *et al.* 2015), iteration is left unstructured (e.g., as in Fogg's eight-step process (2009a)) or iteration is offloaded to a meta-cycle, where a new project is formed based on feedback from a launched *intervention* (Michie *et al.* 2015; OECD 2017). Hence, we highlight the need for alternative formulations of behavioural design process models that can better account for iteration at multiple levels. This leads to our first proposition.

Proposition 1: Effective behavioural design processes enable for reciprocal, co-evolutionary influence *within* and *between* mechanisms and embodiments spaces.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

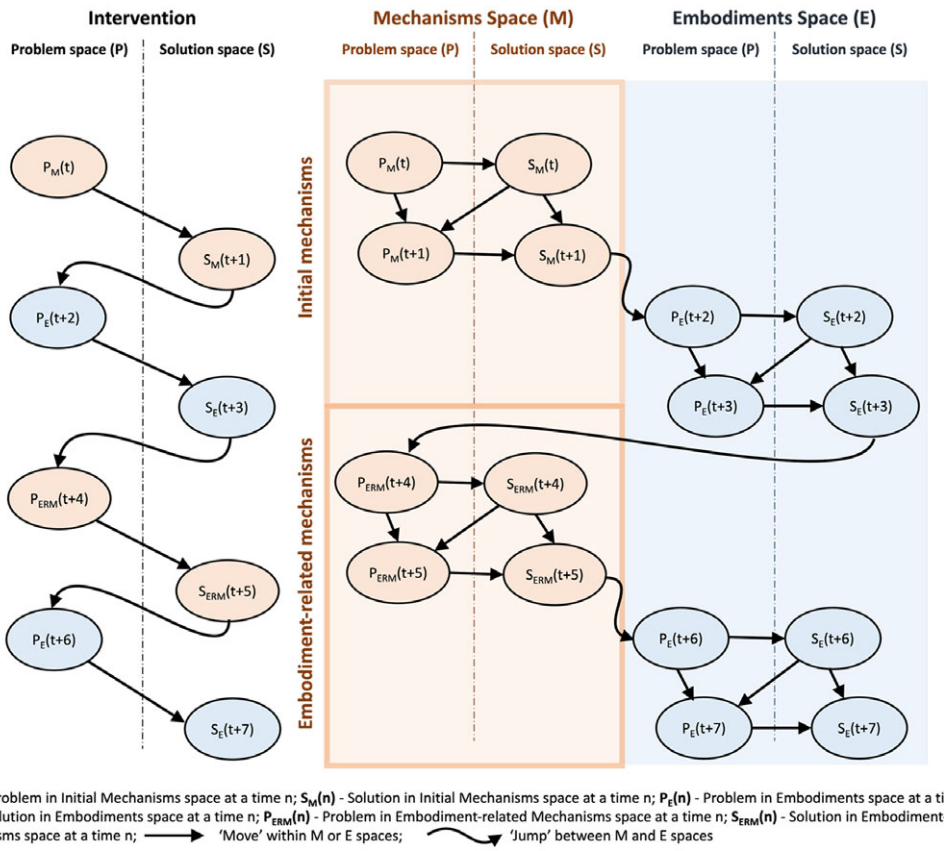


Figure 5. Illustration of co-evolution in behavioural design, denoting co-evolution *within* the embodiments and mechanisms spaces as well as co-evolution between spaces at a higher abstraction level denoted here as the intervention problem/solution spaces in recognition that it links mechanisms and embodiment understanding.

Our findings also draw a direct connection between the extent of co-evolution and understanding and cohesion of the *intervention*, based on *process synergy*. Prior work has focused primarily on conceptualisation of behavioural and behaviour change theory and the specific work needed to deliver relevant theory-based *interventions* defined primarily with respect to their initial *mechanisms* (Michie *et al.* 2008). In contrast, our work highlights the importance of process-focused theory that connects how behavioural design is done to the viability of the delivered *interventions* and the degree to which they leverage the full available design space (i.e., both *mechanisms* and *embodiments* spaces and their interactions). For example, Cash & Joo (2026) elucidate how specific theory, and associated process management, is needed to help mediate interactions between *mechanisms* and *embodiments*-related design work. Notably, this calls into question the typical formulation of a single one-way transition between the *mechanisms* and *embodiments* spaces found in most behavioural design literature (Section 2). However, further research is needed to better understand how process structures such as

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

process synergy impact not just the delivered *intervention* but its ultimate performance in context. This leads to our second proposition.

Proposition 2a and 2b: Increased process synergy in the form of greater reciprocal, co-evolutionary influence (2a) *within* and (2b) *between* mechanisms and embodiments spaces will increase understanding and cohesion of delivered behavioural interventions.

Second, prior work has typically focused on early concretisation of the problem definition, hence making it unclear how iteration can be accommodated (Section 2.1). Our findings offer specific insight into this disconnect by highlighting the higher-level co-evolution between *intervention*-level spaces illustrated in Figure 5. Specifically, we found two and sometimes more jumps between the lower-level *mechanisms* and *embodiments* spaces associated with feedback regarding (i) how the initial *mechanisms* space can be translated into an *embodiment* and (ii) how the *mechanisms* space should be iterated based on feedback in relation *embodiments*-related *mechanisms* (Figure 4). Typically, this second mode happened at least once, but in some projects, it occurred multiple times as different *embodiment* approaches were tested and iterated, necessitating refinement of the *mechanisms* space (e.g., Cases 3, 7 and 10). Here, iteration was typically triggered by additional behavioural insights associated with the testing of *intervention* prototypes or the introduction of additional behavioural concerns associated with *intervention* uptake and use, based on expert review, user feedback or test implementation. While all cases included at least one iterative jump to allow for *embodiments*-related *mechanisms*, further jumps were sometimes necessary when significant issues emerged in the *embodiments* space. For example, in some cases the initial *embodiment* was found to need complete revision (as in Case 5), need additional elements (as in Case 3) or require ongoing processes to support uptake and use (as in Case 10). These changes were significant enough to require iteration of the *mechanisms* space. However, teams also needed to make explicit choices about how to manage this in context. For example, in Case 10 the team pivoted towards a more service-like formulation to allow for ongoing updates, while the team in Case 5 extended their process to allow for additional testing. Yet such changes or extensions were not always possible. For example, when constrained by time or budget, some *interventions* were delivered with the caveat that further work might be needed (as in Case 11). In these cases, teams typically provided information on how ongoing work might be handled and additional iterations incorporated into the post-project timeframe. Therefore, even when not possible within the constraints of the project timeline, all cases took care to provide for at least one and often two or more major iterations between *embodiments* and *mechanisms* spaces, with the general acknowledgement that these were essential for the ultimate success of *intervention* implementation in context. Literature on co-evolution in design also associates such interactions with the work of experienced designers and draws a link between this and better quality designs (Dorst & Cross 2001; Kavakli & Gero 2002). This suggests an alternative structure to the typical single jump between *mechanisms* and *embodiments* spaces, where, at minimum, an iteration is needed in the *mechanisms* space for each major development or reframing of the *embodiments* space. This forms the basis for our third proposition.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Proposition 3: At minimum, reciprocal, co-evolutionary influence *between* mechanisms and embodiments spaces is necessary with respect to the initial mechanisms and the embodiments-related mechanisms.

Our findings (Figure 5 and propositions) thus help close the gap in understanding associated with the interface between the development of behaviour change *mechanisms* and their *embodiments* (Section 2).

5.2. Wider implications for design theory

Our findings also reveal the need for further development of co-evolutionary theory in order to link process structures and outcomes. Specifically, Proposition 2 highlights a link between process structure and understanding of the final *intervention*. This points to the need for future research to better conceptualise this process structure/output link and, for example, answer questions such as what might constitute too much or too little co-evolution, how co-evolutionary structures relate to specific types of development in the related spaces (linked to Proposition 3) and how this understanding might feed into efforts to model design processes (Fernandes *et al.* 2017). This aligns with general calls to better understand underpinning design processes and mindsets (Lavrsen, Carbon & Daalhuizen 2024). Further, we note that it was necessary to introduce additional visual elements in our explanations of co-evolutionary moves reflecting the extent of moves (move versus jump) and complexity in the interaction and organisation of spaces (e.g., see Figure 4). Thus, while our work does not directly focus on extending a general understanding of co-evolution, our findings hold several significant implications for further work in this area and contribute to the ongoing debate regarding how co-evolution can be developed and visualised (Crilly 2021; Gero, Kannengiesser & Crilly 2022; Cash *et al.* 2023).

5.3. Implications for behavioural design practice and education

In terms of practice, the distinction between development of *mechanisms* and *embodiments* spaces allows for greater clarity in process planning and management. First, Proposition 1 highlights the need to allow for co-evolution of *mechanisms* and *embodiments* spaces even when applying more linear process models (see Section 2). Specifically, behavioural design teams should make iteration an explicit, rather than tacit, part of their process. Key here is the recognition that changes in one space impact the other and need to then be accounted for. For example, if new *mechanisms* are identified as part of a research step, this should trigger iteration of the *embodiment* to examine how these might be practically integrated; might they simply be added to the existing *embodiment* (e.g., an additional function in an app) or might they require wider changes (e.g., shifting from an app. to an app. coupled with a product and communication campaign)? Similarly, changes to the *embodiments* should trigger iteration of the *mechanisms*. For example, shifting from an app. to an app. coupled with a product will introduce additional considerations around uptake, use and disposal of the product element that are distinct from an app. integrated within an existing device. Hence, significant changes in either space should trigger iteration.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Second, Propositions 2 and 3 reveal the need for at least one iteration, but with processes benefiting from more than one where possible within the constraints of time and budget. Critical here is that no matter what *embodiment* emerges, it will introduce new and/or significantly re-contextualise the initially identified *mechanisms*. At minimum there will be ancillary *embodiments*-related *mechanisms* around uptake, upkeep and end-of-life, which are typically *intervention* specific (e.g., an app. will require users to download and update it, as well as take on management of their own change process once the app. becomes unsupported or out of date on the relevant platform). Beyond these, all of our cases identified additional mechanisms either being enabled or directly triggered by their chosen embodiments and hence needed to revisit their initial conceptual models or selected mechanisms with these in mind. It is beyond the scope of this work to address every possible trigger for such iteration, or how this should be managed within the wider constraints of a project (indeed such issues are addressed in the design process and project management literatures). However, it is essential that teams organise their work such that iteration can be incorporated within the process and at minimum allow time to account for *embodiments*-related *mechanisms* and the potential need to revisit research insights or carry out additional work to understand *embodiments*-related uptake and use concerns.

In terms of education, our findings provide a basis for educators to explain the interaction between previously disparate yet complementary process models, such as those by Michie *et al.* (2015) and Fogg (2009b). This allows for a more consistent, theory-based explanation of the functioning, progression and critical dependencies of the behavioural design process. We highlight the need to further develop education around process skills in behavioural design to complement the extensive bodies of work focused on understanding behavioural problems and solutions (Michie *et al.* 2015).

6. Conclusions

This research set out to answer the RQ: *How do behaviour change mechanisms and their embodiments emerge and relate to each other during behavioural design processes*? We address this question by developing an elaborated understanding of co-evolutionary development associated with distinct co-evolution *within* the *mechanisms* and *embodiments* spaces, as well as *between* them (Figure 5). This allowed us to develop several propositional insights regarding the relationship between co-evolutionary process structures, conceptualised as *process synergy* and the development of behavioural design *interventions*. This has implications for behavioural design process theory and prescriptions, as well as highlighting areas of potential future work in more general discussions of co-evolution in design. In particular, not all possible co-evolutionary patterns were observed in our data, suggesting the need to further investigate the significance of specific co-evolutionary structures or sequences – especially across levels of analysis – as well as degrees of co-evolution and direction of the process. Thus, our work highlights the need for further research on process structure in behavioural design in order to complement ongoing work on behavioural problem/solution understanding.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

References

Ajzen, I. 2005 *Attitudes, Personality and Behaviour (Second)*. McGraw-Hill International.

Aunger, R. & **Curtis, V.** 2016 Behaviour centred design: Towards an applied science of behaviour change. *Health Psychology Review* **10** (4), 425–446; doi:10.1080/17437199.2016.1219673.

Baxter, W., **Mandeno, P.**, **Aunger, R.** & **Brial, E.** 2025 Setting-driven design: A context-driven approach to behavioural design. *Design Science* **11** (e35), 1–39; doi:10.1017/dsj.2025.10025.

Bay Brix Nielsen, C. K. E., **Cash, P.** & **Daalhuizen, J.** 2024 The power and potential of behavioural design: Practice, methodology, and ethics. *Journal of Engineering Design* **35** (5), 504–542; doi:10.1080/09544828.2024.2322897.

Bhamra, T., **Lilley, D.** & **Tang, T.** 2011 Design for sustainable behaviour: Using products to change consumer behaviour. *The Design Journal* **14** (4), 427–445; doi:10.2752/175630611X13091688930453.

Bohlen, L. C., **Michie, S.**, **de Bruin, M.**, **Rothman, A. J.**, **Kelly, M. P.**, **Groarke, H. N. K.**, **Carey, R. N.**, **Hale, J.** & **Johnston, M.** 2020 Do combinations of behavior change techniques that occur frequently in interventions reflect underlying theory? *Annals of Behavioral Medicine* **54** (11), 827–842; doi:10.1093/abm/kaaa078.

Cao, W., **Cao, X.** & **Sutherland, A. D.** 2025 Planning for the unexpected and unintended effects of mHealth interventions: Systematic review. *Systematic Review. Journal of Medical Internet Research* **27**, e68909–e68909; doi:10.2196/68909.

Cash, P. & **Joo, J.** 2026 Complex behavioural design (CBD): Exploring how behavioural design teams develop systemic interventions. *Designing*. doi:10.1177/3049767126 1429993.

Cash, P., **Hartlev, C. G.** & **Durazo, C. B.** 2017 Behavioural design: A process for integrating behaviour change and design. *Design Studies* **48**, 96–128; doi:10.1016/j.destud.2016.10.001.

Cash, P., **Khadilkar, P.**, **Jensen, J.**, **Dusterdich, C.** & **Mugge, R.** 2020 Designing behaviour change: A behavioural problem/solution (BPS) matrix. *International Journal of Design* **14** (2), 65.

Cash, P., **Valles Gamundi, X.**, **Echstrom, I.** & **Daalhuizen, J.** 2022 Method use in behavioural design: What, how, and why? *International Journal of Design* **16** (1), 1–21.

Cash, P., **Gonçalves, M.** & **Dorst, K.** 2023 Method in their madness: Explaining how designers think and act through the cognitive co-evolution model. *Design Studies* **88**, 101219; doi:10.1016/j.destud.2023.101219.

Clune, S. & **Lockton, D.** 2017 Design for behavioural change and sustainability. In *Design for Behaviour Change* (eds. Niedderer, K., Clune, S., Ludden, G.), pp. 166–183. Routledge.

Colquitt, J. A. & **Zapata-Phelan, C. P.** 2007 Trends in theory building and theory testing: A five-decade study of the Academy of management journal. *Academy of Management Journal* **50** (6), 1281–1303; doi:10.5465/amj.2007.28165855.

Crilly, N. 2021 The evolution of co-evolution" (part I): problem solving, problem finding, and their interaction in design and other creative practices. *She Ji* **7** (3), 309–332; doi:10.1016/j.sheji.2021.07.003.

Crilly, N. & **Moroșanu Firth, R.** 2019 Creativity and fixation in the real world: Three case studies of invention, design and innovation. *Design Studies* **64**, 169–212; doi:10.1016/j.destud.2019.07.003.

Datta, S. & **Mullainathan, S.** 2014 Behavioral design: A new approach to development policy. *Review of Income and Wealth* **60** (1), 7–35; doi:10.1111/roiw.12093.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Dorst, K. 2019 Co-evolution and emergence in design. *Design Studies* **65**, 60–77; doi: 10.1016/j.destud.2019.10.005.

Dorst, K. & **Cross, N.** 2001 Creativity in the design process: Co-evolution of problem-solution. *Design Studies* **22** (5), 425–437; doi:10.1016/S0142-694X(01)00009-6.

Eisenhardt, K. M. & **Graebner, M. E.** 2007 Theory building from cases: Opportunities and challenges. *Academy of Management Journal* **50** (1), 25–32; doi:10.5465/amj.2007.24160888.

Fernandes, J. V., **Henriques, E.**, **Silva, A.** & **Pimentel, C.** 2017 Modelling the dynamics of complex early design processes: An agent-based approach. *Design Science* **3**; doi:10.1017/dsj.2017.17.

Fogg, B. J. 2009 Creating persuasive technologies: an eight-step design process. In *Proceedings of the 4th International Conference on Persuasive Technology (Persuasive '09)*. Association for Computing Machinery, New York, NY, USA, Article 44, 1–6. https://doi.org/10.1145/1541948.1542005

Fogg, B. J. 2009b The behavior grid: 35 ways behavior can change. *ACM International Conference Proceeding Series* **350**, 1–5; doi:10.1145/1541948.1542001.

Francis, J. J. J., **Stockton, C.**, **Eccles, M. P. M. P.**, **Johnston, M.**, **Cuthbertson, B. H. B. H.**, **Grimshaw, J. M. J. M.**, **Hyde, C.**, **Tinmouth, A.** & **Stanworth, S. J. S. J.** 2009 Evidence-based selection of theories for designing behaviour change interventions: Using methods based on theoretical construct domains to understand clinicians' blood transfusion behaviour. *British Journal of Health Psychology* **14** (4), 625–646; doi:10.1348/135910708X397025.

Gero, J. S., **Kannengiesser, U.** & **Crilly, N.** 2022 Abstracting and formalising the design co-evolution model. *Design Science* **8**, e14; doi:10.1017/dsj.2022.10.

Giacomin, J. 2014 What is human centred design? *The Design Journal* **17** (4), 606–623; doi: 10.2752/175630614X14056185480186.

Gibbert, M., **Ruigrok, W.** & **Wicki, B.** 2008 What passes as a rigorous case study? *Strategic Management Journal* **29** (13), 1465–1474; doi:10.1002/smj.722.

Guest, G., **Bunce, A.** & **Johnson, L.** 2006 How many interviews are enough?: An experiment with data saturation and variability *Field Methods* **18** (1), 59–82; doi: 10.1177/1525822X05279903.

Hagger, M. S. & **Weed, M.** 2019 DEBATE: Do interventions based on behavioral theory work in the real world? *International Journal of Behavioral Nutrition and Physical Activity* **16** (1), 36; doi:10.1186/s12966-019-0795-4.

Hagger, M. S., **Moyers, S.**, **McAnally, K.** & **McKinley, L. E.** 2020 Known knowns and known unknowns on behavior change interventions and mechanisms of action. *Health Psychology Review* **14** (1), 199–212; doi:10.1080/17437199.2020.1719184.

Human Centered Design Toolkit. 2015 IDEO. Retrieved http://www.ideo.com/work/human-centered-design-toolkit/.

Kavakli, M. & **Gero, J. S.** 2002 The structure of concurrent cognitive actions: A case study on novice and expert designers. *Design Studies* **23** (1), 25–40; doi:10.1016/S0142-694X(01)00021-7.

Khadilkar, P. & **Cash, P.** 2020 Understanding behavioural design: Barriers and enablers. *Journal of Engineering Design* **31** (10), 508–529; doi:10.1080/09544828.2020.1836611.

Langley, A. 1999 Strategies for theorizing from process data. *The Academy of Management Review* **24** (4), 691–710; doi:10.2307/259349.

Lavrsen, J. C., **Carbon, C. C.** & **Daalhuizen, J.** 2024 Measuring design mindset: Developing the design mindset inventory through its relationship with ambiguity tolerance, self-efficacy and sensation-seeking. *Design Science* **10**; doi:10.1017/dsj.2024.36.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Lilley, D. 2009 Design for sustainable behaviour: Strategies and perceptions. *Design Studies* **30** (6), 704–720; doi:10.1016/j.destud.2009.05.001.

Lockton, D., **Harrison, D.** & **Stanton, N. A. N. A.** 2010 The design with intent method: A design tool for influencing user behaviour. *Applied Ergonomics* **41** (3), 382–392; doi:10.1016/j.apergo.2009.09.001.

Maher, M. & **Tang, H.-H.** 2003 Co-evolution as a computational and cognitive model of design. *Research in Engineering Design* **14** (1), 47–64; doi:10.1007/s00163-002-0016-y.

Maher, M. L., **Poon, J.** & **Boulanger, S.** 1996 Formalising design exploration as co-evolution. In *Advances in Formal Design Methods for CAD* (ed. J. Gero & F. Sudweeks), pp. 3–30. Springer.

Martinec, T., **Škec, S.**, **Perišić, M. M.** & **Štorga, M.** 2020 Revisiting problem-solution co-evolution in the context of team conceptual design activity. *Applied Sciences* **10** (18); doi:10.3390/app10186303.

Michie, S. & **West, R.** 2013 Behaviour change theory and evidence: A presentation to government. *Health Psychology Review* **7** (1), 1–22; doi:10.1080/17437199.2011.649445.

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* **57** (4), 660–680; doi:10.1111/j.1464-0597.2008.00341.x.

Michie, S., **Richardson, M.**, **Johnston, M.**, **Abraham, C.**, **Francis, J.**, **Hardeman, W.**, **Eccles, M. P.**, **Cane, J.** & **Wood, C. E.** 2013 The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine* **46** (1), 81–95; doi:10.1007/s12160-013-9486-6.

Michie, S., **Atkins, L.** & **West, R.** 2015 The behaviour change wheel: A guide to designing interventions. In *Great Britain: Silverback Publishing*, 1st Edn. Silverback Publishing.

Michie, S., **Thomas, J.**, **Mac Aonghusa, P.**, **West, R.**, **Johnston, M.**, **Kelly, M. P.**, **Shawe-Taylor, J.**, **Hastings, J.**, **Bonin, F.** & **O'Mara-Eves, A.** 2020 The human behaviour-change project: An artificial intelligence system to answer questions about changing behaviour. *Wellcome Open Research* **5**, 122; doi:10.12688/wellcomeopenres.15900.1.

Miles, M. B., **Huberman, A. M.** & **Saldaña, J.** 2014 *Qualitative Data Analysis: A Methods Sourcebook*, 3rd Edn. Sage Publications.

Neuman, W. L. 2011 *Social Research Methods: Qualitative and Quantitative Approaches*. Pearson.

Niedderer, K., **Clune, S.** & **Ludden, G.** 2017 *Design for Behaviour Change: Theories and Practices of Designing for Change*. (1st Edn.) Taylor and Francis.

Nielsen, C. K. E. B. B., **Cash, P.** & **Daalhuizen, J.** 2018 The behavioural design solution space: Examining the distribution of ideas generated by expert behavioural designers. In *Ds92: Proceedings of the Design 2018 15th International Design Conference*, (eds. Marjanović D., Štorga M., Škec S., Bojčetić N., Pavković N.). 1981–1990. Design Society.

OECD. 2017 *Behavioural Insights and Public Policy. Lessons from Around the World*. OECD Publishing.

OECD. 2019 *Tools and Ethics for Applied Behavioural Insights: The Basic Toolkit*. (First). OECD Publishing. https://www.oecd.org/gov/regulatory-policy/tools-and-ethics-for-applied-behavioural-insights-the-basic-toolkit-9ea76a8f-en.htm.

Papalambros, P. Y. 2015 Design science: Why, what and how. *Design Science* **1**, e1; doi:10.1017/dsj.2015.1.

Robson, C. & **McCartan, K.** 2011 *Real World Research*, 4th Edn. Wiley.

Rogers, E. M. 1983 *Diffusion of Innovations*, 3rd Edn. The Free Press.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press

Roozenburg, N. & **Eekels, J.** 1995 *Product Design: Fundamentals and Methods*. John Wiley & Sons Ltd.

Schmidt, R. 2020 Strange bedfellows: Design research and behavioral design. In *Synergy - DRS International Conference 2020* (ed. S. Boess, M. Cheung & R. Cain). Design Research Society. doi:10.21606/drs.2020.252.

Schmidt, R. 2024 A model for choice infrastructure: Looking beyond choice architecture in behavioral public policy. *Behavioural Public Policy* **8** (3), 415–440; doi:10.1017/bpp.2021.44.

Smulders, F., **Dorst, K.** & **Reyman, I.** 2009 Modelling co-evolution in design practice. In *DS 58–2: Proceedings of ICED 09, the 17th International Conference on Engineering Design, Vol. 2, Design Theory and Research Methodology*. (eds. Norell Bergendahl, M.; Grimheden, M.; Leifer, L.; Skogstad, P.; Lindemann, U.), 335–346. Design Society.

Taylor, D., **Bury, M.**, **Campling, N.**, **Carter, S.**, **Garfied, S.**, **Newbould, J.** & **Rennie, T.** 2006 *A Review of the Use of the Health Belief Model (HBM), the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour (TPB) and the Trans-Theoretical Model (TTM) to Study and Predict Health Related Behaviour Change*, pp. 1–215. National Institute for Health and Clinical Excellence.

Thaler, R. & **Sunstein, C.** 2008 *Nudge: Improving Decisions about Health, Wealth, and Happiness*. Yale University Press.

Tromp, N. & **Hekkert, P.** 2014 Social implication design (SID) - A design method to exploit the unique value of the artefact to counteract social problems. In *Proceedings of the DRS 2014*, (eds. Lim, Y., Niedderer, K., Redström, J., Stolterman, E. and Valtonen, A. 15). Design Research Society.

Tromp, N., **Hekkert, P.** & **Verbeek, P.-P.** 2011 Design for socially responsible behavior: A classification of influence based on intended user experience. *Design Issues* **27** (3), 3–19; doi:10.1162/DESI_a_00087.

Voorheis, P., **Zhao, A.**, **Kuluski, K.**, **Pham, Q.**, **Scott, T.**, **Sztur, P.**, **Khanna, N.**, **Ibrahim, M.** & **Petch, J.** 2022 Integrating behavioral science and design thinking to develop mobile health interventions: Systematic scoping review. *JMIR mHealth and uHealth* **10**(3), e35799 doi:10.2196/35799.

Wiltschnig, S., **Christensen, B. T.** & **Ball, L. J.** 2013 Collaborative problem--solution co-evolution in creative design. *Design Studies* **34** (5), 515–542; doi:10.1016/j.destud.2013.01.002.

Yin, R. K. 2014 *Case Study Research and Applications: Design and Methods*, 5th Edn. Sage Publications.

https://doi.org/10.1017/dsj.2026.10070 Published online by Cambridge University Press