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DISSERTATIONS ON NATURAL SCIENCES

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FARHAT-UL-AIN

**BRINGING TOGETHER INTERVENTION AND
INTERACTION DESIGN WITH THE DIGITAL
HEALTH BEHAVIOUR CHANGE TOOLKIT**

Tallinn 2025

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THE DIGITAL HEALTH BEHAVIOUR CHANGE TOOLKIT**

School of Digital Technologies, Tallinn University, Tallinn, Estonia

The dissertation was accepted for the defence of the degree of *Doctor Philosophiae* in Information Society Technologies by the Doctoral Council of Natural Sciences of Tallinn University on November 21th, 2025.

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LIST OF PUBLICATIONS

The dissertation is based on these five papers, which are referred to in the analytical overview by Roman numerals:

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- II. Farhat-ul-Ain, Toom, K., & Tomberg, V. (2025). Enriched with Behaviour Theory Topic Guide Template for Digital Behaviour Change Interventions. In: Plácido da Silva, H., Cipresso, P. (eds) Computer-Human Interaction Research and Applications. CHIRA 2024. Communications in Computer and Information Science, vol 2370. Springer, Cham. https://doi.org/10.1007/978-3-031-82633-7_13
- III. Farhat-ul-Ain, Akhmetzyanova, D., Matias, I., & Tomberg, V. (2024). Behaviour Models-Enriched User Personas for Digital Behaviour Change Interventions. Proceedings of the 17th International Conference on Pervasive Technologies Related to Assistive Environments, 140–146. <https://doi.org/10.1145/3652037.3652069>
- IV. Farhat-ul-Ain, Popovits, O., & Tomberg, V. (2022). Mapping Behavior Change Wheel Techniques to Digital Behavior Change Interventions: Review. In: Kurosu, M. (eds) Human-Computer Interaction. User Experience and Behavior. HCII 2022. Lecture Notes in Computer Science, vol 13304. Springer, Cham. https://doi.org/10.1007/978-3-031-05412-9_20
- V. Farhat-ul-Ain, Popovitz, O., Amirgaliyeva, G., & Tomberg, V. (2025). Supporting Behaviour Change Techniques with Interaction Design Patterns. In: Plácido da Silva, H., Cipresso, P. (eds) Computer-Human Interaction Research and Applications. CHIRA 2024. Communications in Computer and Information Science, vol 2370. Springer, Cham. https://doi.org/10.1007/978-3-031-82633-7_22

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- VII. Farhat-ul-Ain, Tomberg, V., & da Silva, H. P. (2022). Towards Adapting Questionnaires for Long-Term Online Dynamic Monitoring of Patients. IEEE 30th International Requirements Engineering Conference Workshops (REW), 30–37. <https://doi.org/10.1109/REW56159.2022.00015>
- VIII. Matias, I., Farhat-ul-Ain., Akhmetzyanova, D., & Tomberg, V. (2024). Modelling Users for User Modelling: Dynamic Personas for Improved Personalisation in Digital Behaviour Change. In Adjunct Proceedings of the 32nd ACM Conference on User Modeling, Adaptation and Personalization (UMAP Adjunct '24). 445–451. <https://doi.org/10.1145/3631700.3665241>

- IX. Farhat-ul-Ain., Port, K., & Tomberg, V. (2022). Digital Self-monitoring to Improve Perceptions Regarding Physical Activity: A Case of Quantifying Self with University Students. *Communications in Computer and Information Science*, 1581 CCIS, 259–266. https://doi.org/10.1007/978-3-031-06388-6_34

Author's contribution

- I. Farhat-ul-Ain is the primary author of this research paper. She reviewed the literature and synthesised the results. She also wrote the initial draft of the paper.
- II. Farhat-ul-Ain is the primary author of this article. She developed the research question, created a research design, performed data analysis and interpretation, and wrote the initial draft of the manuscript.
- III. Farhat-ul-Ain is the primary author of this article. She developed the research question, created the research design, performed data analysis and interpretation, wrote the manuscript, and revised it.
- IV. Farhat-ul-Ain is the primary author of this article. She reviewed the literature and synthesised the results. She also wrote the initial draft of the paper.
- V. Farhat-ul-Ain is the primary author of this article. She also wrote the initial draft and revised the manuscript. Farhat supervised Popovitz and Amirgaliyeva in developing design patterns. She planned and conducted expert evaluations and analysed the data.

ABSTRACT

Digital Behaviour Change Interventions (DBCIs) have become essential tools for promoting and sustaining healthy behaviour. The design of DBCIs is inherently multidisciplinary, requiring contributions from both *intervention design* and *interaction design*. *Intervention design* provides evidence-based theories that highlight various psychological, social, and environmental determinants influencing behaviour and provide behaviour change techniques that facilitate behaviour change. Interaction design focuses on the interactive behaviour of digital products. Interaction design approaches such as User-Centred Design and Goal-Directed Design provide structured processes that involve a logical sequence of interaction methods (for example, interviews, focus groups, and user personas) for understanding user needs, goals, and motivations and using them for designing digital products.

Despite recognising this multidisciplinary nature, the use of behavioural theories in interaction design practice for developing DBCIS remains limited. Interaction designers are proficient in various interaction design methods, such as interviews, focus groups, and user personas. However, the regular tools that support these methods are not adequately tailored to capture behaviour change-related insights. Consequently, interaction designers struggle to identify the specific needs, barriers, and facilitators of behaviour change, complicating design-related decision-making. There is a lack of structured guidance on integrating insights from behaviour change theories into the design process. Therefore, there is a need for an approach that can assist interaction design in utilising insights from behaviour change theory.

To overcome the challenges mentioned above, the main objectives of this research are to enhance and enrich existing tools that support interaction design methods to facilitate the design of DBCIs for health by integrating behaviour change theories into interaction design tools. To achieve this, a Digital Health Behaviour Change (DHBC) toolkit for interaction designers was developed to support the integration of insights from behaviour change theories into the design process, resulting in four contributions. This study adopted both *Research for Design* and *Research through Design* approaches, combined with an iterative and reflective process, to develop practical tools that support designers in integrating behaviour change theory into the design of DBCIs.

The first contribution includes a *theory-enriched user research topic guide* for supporting theory-based interviews/focus groups. The COM-B Model (Capability, Opportunity, Motivation - Behaviour) and the Transtheoretical Model of Change were selected to develop the topic guide. The purpose is to support designers with a generic topic guide that can be easily adapted and utilised in various health application domains. The proposed *theory-enriched user research topic guide template* was evaluated using the case study method. Results indicated various behaviour change-related needs of the children and highlighted age-related differences in children's

skills, independence, and motivation to manage diabetes, highlighting the usefulness of the proposed toolkit in identifying behaviour change-specific needs.

The second contribution includes a *theory-enriched user persona guide and template*. It included specific sections related to behaviour change goals, COM-B-based barriers and challenges, and user segments based on a stage of change. Expert and practitioner evaluations were conducted to assess the proposed *theory-enriched user persona guide*. All experts and practitioners supported adding specific sections related to behaviour change to the regular persona template, which is useful and suggested some areas of improvement.

Thirdly, design patterns for six popular behaviour change techniques were developed and evaluated by experts. Practitioners found the descriptions and examples of the design patterns useful, clear, and comprehensible.

The resulting comprehensive DHBC toolkit includes the final versions of the proposed tools, along with necessary guidelines for designers.

This work aims to help interaction designers working in teams that may lack access to behavioural experts or seek to enhance communication and collaboration with them. Future work involves further refining these tools by addressing identified areas for improvement based on expert feedback and enhancing their applicability across diverse design contexts. Equipping interaction designers with tools that can lead to better DBCI design can also foster improved individual well-being and reduce pressure on healthcare systems, thus contributing to both design practice and a broader societal impact.

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LIST OF ABBREVIATIONS

DBCIs – Digital Behaviour Change Interventions

TDF–Theoretical Domain Framework

COM-B model – Capability, Opportunity, Motivation- Behaviour Model

BCTs – Behaviour Change Techniques

TTM – Transtheoretical Model of Change

BCW – Behaviour Change Wheel

GDD – Goal-Directed Design

DHBC Toolkit – Digital Health Behaviour Change Toolkit

GLOSSARY

Term	Definition
Interaction Design	Interaction design aims to define the behaviour of products and systems in response to their users to facilitate meaningful user interactions
Interaction Design Approaches	Interaction design approaches provide a well-defined sequence of phases that structure the overall design process.
Interaction Design Methods	Each phase can employ various methods, such as interviews and observations that support data collection, synthesis, ideation, and evaluation, enabling designers to systematically progress from one phase to another.
Interaction Design Tools	Various pre-defined tools that support the application of methods, such as guides, templates, and design patterns
Intervention Design	A structured process for understanding determinants influencing behaviour and selecting behaviour change techniques.
Behaviour Change Theories	Frameworks that describe the psychological, social, and contextual determinants of behaviour and explain how these determinants, such as motivation, capability, and opportunity, can be targeted to facilitate behavioural change.
Behaviour Change Techniques (BCTs)	Observable, irreducible and replicable components of interventions, such as goal setting, are selected to target specific determinants influencing behaviour.

INTRODUCTION

Behavioural change has been a critical focus of attention across multiple fields such as psychology, education, behavioural economics, public health, marketing, etc. It is traditionally achieved through various interventions. An intervention is a structured set of actions, strategies, or techniques designed to bring about a desired change in behaviour, cognition, or health outcomes. Traditionally, behaviour change interventions have been delivered in face-to-face settings, but advancements in digital technology have opened new opportunities for their design and delivery. The main goal is to use digital technologies, such as mobile and web-based applications, to encourage, support, and maintain positive behaviour change. Such digital technologies are also referred to as *Digital Behaviour Change Interventions* (DBCIs). DBCIs are applied in different contexts, including health behaviours, promotion of sustainability-related behaviours (for example, reducing energy consumption and promoting sustainable transportation choices), and education (for example, classroom behaviour) (Asbjørnsen et al., 2024; Haleem et al., 2022; Piscicelli, 2023; Shadiev et al., 2024; Xia et al., 2024). Oinas-Kukkonen et al. (2010) mentioned them as behaviour change support systems and defined them as “a sociotechnical information system with psychological and behavioural outcomes designed to form, alter, or reinforce attitudes, behaviours or an act of complying without using coercion or deception”.

The use of DBCIs to monitor and manage health, and specifically to support health behaviour change, is continuously increasing (Evans et al., 2022; Free et al., 2013; Taj et al., 2019). Currently, DBCIs for health have been employed successfully to promote physical activity behaviours (Laranjo et al., 2021; Pradal-Cano et al., 2020), weight management (Hutchesson et al., 2016), nutrition and water intake (Chiu et al., 2009; Mamykina et al., 2011), smoking cessation (Hoepfner et al., 2017; Whittaker et al., 2016), and alcohol reduction (Sohi et al., 2023). Beyond supporting health behaviours, these interventions can also improve outcomes for individuals with long-term conditions, such as diabetes and cardiovascular disease (Alsaman et al., 2020; Castensøe-Seidenfaden et al., 2018; Eyles et al., 2014; Health, 2019; Murray et al., 2005). In 2023, the European mHealth market generated around 16 million euros in revenue and is expected to grow at a compound annual growth rate of 14.6% between 2024 and 2030. Among the different market segments, mHealth applications accounted for the highest revenue share, highlighting the growing adoption of digital health solutions across the region (Grand View Research, 2024).

Designing DBCIs for health requires theoretical and practical contributions related to different fields of knowledge. *Interaction design* is the discipline that aims to define the behaviour of products and systems in response to their users (Cooper et al., 2014; Jones & Marsden, 2006; Saffer, 2009). Methodological design approaches like User-Centred design and Goal-Directed design focused on gathering knowledge about the users, their needs, goals, motivation, expectations and frustrations. They

involve generating various models of the users and their behaviour, developing scenarios for ideal user interactions and defining users' requirements for the potential digital product (Cooper et al., 2014). Various *interaction design* methods, such as interviews, focus groups, personas, sketching, and design patterns, facilitate the overall design process.

Digital technologies, such as mobile applications, cannot aid in behaviour change itself. Rather, the behaviour change can be achieved through Behaviour Change Techniques (BCTs), such as reminders, notifications, and rewards, which are implemented as features in DBCIs. The Behaviour Change Technique is “*an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour; that is, a technique is proposed to be an active ingredient*” (Michie et al., 2013). The BCTs should be carefully selected to modify the factors or *determinants influencing individual behaviours*, such as motivation, beliefs, social pressures, etc. *Intervention design* provides a structured framework for systematically identifying determinants influencing behaviour and selecting evidence-based Behaviour Change Techniques (BCTs) to support behavioural change. Thus, the *intervention design* forms the foundation for behaviour change interventions.

The design of Digital Behaviour Change Interventions (DBCI) is inherently multidisciplinary, necessitating contributions from both *intervention design* and *interaction design*. Although *intervention design* provides extensive and well-documented knowledge, such as behaviour change theories, models and frameworks (Michie et al., 2011; Michie, West, et al., 2014; Skivington et al., 2021). Interaction designers possess limited domain-specific knowledge regarding established behaviour change theories and processes crucial for designing DBCI (Konstanti et al., 2022). As a result, interaction designers struggle to identify the specific needs, barriers, and facilitators of behaviour change, making it difficult to reach theory-informed design-related decisions. To overcome this challenge, designers need an approach that can help explicitly integrate behavioural theories into their practice.

The current thesis focuses on the development and evaluation of an approach for interaction designers that combines intervention and *interaction design* via shaping existing *interaction design* methods. This thesis integrates concepts from two distinct fields: **interaction design** and **intervention design**. Figure 1. An Overview of Basic Terminologies Used in the Thesis provides an overview of the key terminologies used in this thesis and clarifies how concepts from *interaction design* and *intervention design* are applied.

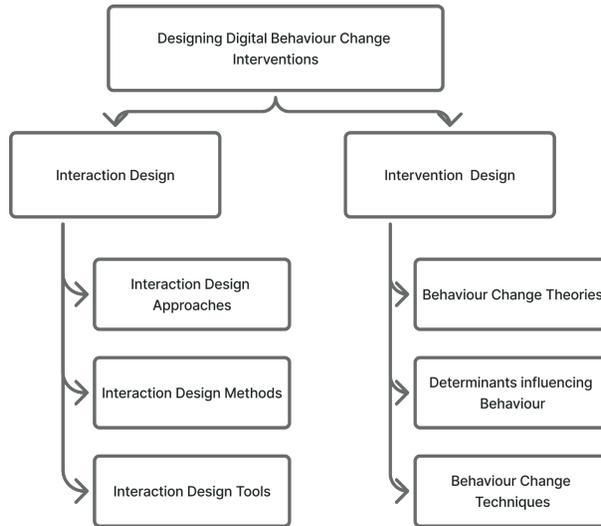


Figure 1. An Overview of Basic Terminologies Used in the Thesis

Interaction design aims to define the behaviour of products and systems in response to their users to facilitate meaningful user interactions. It is supported by *interaction design approaches*, which provide a well-defined sequence of phases that structure the overall design process. Each phase can employ various *interaction design methods*, such as interviews and observations, that support data collection, synthesis, ideation, and evaluation, enabling designers to systematically progress from one phase to another. In addition, various *interaction design tools*, such as guides, templates, and design patterns, help support the application of these methods in practice. *Intervention design* is a structured process for understanding determinants influencing behaviour and selecting appropriate behaviour change techniques. It is grounded in *behaviour change theories*, which describe the psychological, social, and contextual *determinants influencing behaviour* and explain how these determinants can be targeted to facilitate behavioural change. *Behaviour Change Techniques (BCTs)* are observable, irreducible, and replicable components of interventions, such as goal setting, selected to target specific determinants influencing behaviour.

The rest of the dissertation is organised as follows. *Section 1* presents the theoretical foundation for *interaction design* and *intervention design*. *Section 2* highlights related works and identifies research gaps. *Section 3* outlines the research problem, hypothesis, research questions, and objectives, which are formulated to address the research questions. *Section 4* explains the research methodology employed in this thesis. *Section 5* presents the results and research contributions of this thesis. *Section 6* presents discussions on the results and recommendations for designers. Lastly, the dissertation concludes by outlining key research limitations and presenting directions for future work

1. THEORETICAL BACKGROUND

This section offers background information on intervention and interaction design, highlighting their importance in designing DBCIs for health.

1.1. INTERVENTION DESIGN FOR HEALTH DIGITAL BEHAVIOUR CHANGE INTERVENTIONS

Behaviour change interventions aim to modify determinants of behaviour such as knowledge, skills, attitudes, feelings, beliefs, social environment and others, and to help achieve behavioural goals (Davis et al., 2015; Michie, West, et al., 2014; Michie & Johnston, 2012). Behaviour change theories, models and frameworks play a crucial role in the development and evaluation phases of behaviour *intervention design*.

Theories explain the reasons why behaviour may occur by considering a number of predictors and their causal associations with particular behaviour (Bartholomew & Mullen, 2011; Davis et al., 2015). For example, the *Theory of Planned Behaviour* highlights three determinants (attitudes, subjective norms and perceived control) that could lead to intention formation, leading to behaviour change (Ajzen, 1991). Other theories, such as the Transtheoretical Model of Change (TTM), focus on how individuals progress through different stages of change. TTM helps identify an individual's current stage of change, and allows interventions to be tailored to the needs, barriers, and motivators according to stage (Prochaska & Velicer, 1997). TTM provides a stage-based model for understanding how individuals progress through the behaviour change process. It outlines six stages: precontemplation stage (not yet considering change), contemplation stage (thinking about change), preparation (intending and planning to change), action stage (actively making changes), maintenance (sustaining the new behaviour), and relapse stage (individuals reverting to the previous stage). This shows that people with the same target behaviour may be at different stages of change, and they progress through these stages gradually. TTM reflects that behaviour change is a long-term dynamic process and must be considered while designing for behaviour change.

Theories also help in evaluating the overall effectiveness of the interventions and refining the interventions (Bartholomew & Mullen, 2011; Davis et al., 2015; French et al., 2012; Moller et al., 2017). For example, if an intervention is aimed at encouraging physical activity, a Theory of Planned Behaviour can help assess how the intervention is impacting the user's attitudes towards exercise, their perceived control over physical activity, and social influences (e.g., support from family and friends). Evaluating these factors through the theoretical lens ensures that the intervention is targeting the right components. If the intervention outcomes are not achieved, theories help pinpoint which determinants of behaviour in the intervention need modification (for example, a change of attitude).

Given the abundance and complexity of behaviour change theories and issues related to selecting them, the Theoretical Domain Framework (TDF) was proposed (Cane et al., 2012). The TDF model combined thirty-three health behaviour change theories (twenty-eight determinants of behaviour) into fourteen domains. Later, these fourteen domains were further classified into three key components (Michie et al., 2011): Capability (C), Opportunity (O), and Motivation (M), referred to as the COM-B model. The details related to the COM-B model are presented in Table 1 (extracted from *Paper II*).

Table 1. Description of COM-B Components (From *Paper II*)

COM-B Components	Description
 Capability	<ul style="list-style-type: none"> • Physical capability refers to an individual's physical skills and abilities to perform a behaviour (TDF domains: physical skills) • Psychological capability encompasses cognitive resources, knowledge, and understanding necessary to perform a behaviour (TDF domains: knowledge, memory, attention and decision-making processes, behavioural regulation)
 Opportunity	<ul style="list-style-type: none"> • Social opportunity pertains to the external influences and social norms that facilitate or hinder behaviour (TDF domains: social influences, e.g. norms, social pressures) • Physical opportunity involves environmental factors and resources that enable behaviour enactment (TDF domains: environmental context and resources, e.g., time and money)
 Motivation	<ul style="list-style-type: none"> • Reflective motivation represents conscious intentions, goals, and beliefs about abilities and consequences that drive behaviour (TDF domains: Belief about capability, belief about consequences, roles and identity, intention to perform behaviour, goals, optimism) • Automatic motivation involves automatic responses, emotions, and habits and routines that influence behaviour (TDF domains: emotions, reinforcement)

Behaviour change frameworks such as the Medical Research Council Framework (Skivington et al., 2021) and Behaviour Change Wheel (Michie, Atkins, et al., 2014; Michie et al., 2011) guide the overall process for designing behaviour change interventions. The Medical Research Council Framework (Skivington et al., 2021) divides the *intervention design* process into four phases. The first phase, *developing and designing an intervention*, involves understanding the determinants of behaviour based on behaviour change theories and selecting the appropriate Behaviour Change Techniques (BCTs). This often requires qualitative methods, such as interviews, focus groups, and observations. The *feasibility and evaluation phases* assess the intervention's feasibility and overall effectiveness, respectively. Finally, the *implementation phase* involves efforts to implement the interventions on a larger scale.

To help in the process of developing behaviour change interventions, Michie et al. (2014; 2011), proposed the Behaviour Change Wheel model that consists of three key phases: (I) Understanding the behaviour, (II) Identifying intervention functions, and (III) Implementing the intervention (Figure 2). The first phase of understanding the target behaviour involves selecting the specific target behaviour for change and identifying psychological determinants of behaviour based on the COM-B model. Behaviour change interventions focus on particular target behaviours to achieve long-term behavioural goals (For example, reducing weight could involve setting a specific target behaviour, such as walking for 45 minutes each evening). Once a target behaviour is defined, user research methods such as in-depth interviews, focus groups, or questionnaires are used to identify users' psychological determinants of behaviour.

Phase I: Understand the Behaviour	Phase II: Identify Intervention Options	Phase III: Identify Content and Implementation Options
i. Define the problem in behavioural terms ii. Select the target behaviour iii. Specify the target behaviour iv. Identify what needs to change	Identify: v. Intervention functions vi. Policy categories	Identify: vii. Behaviour change techniques viii. Mode of Delivery

Figure 2. Phases of Developing Behaviour Change Interventions

The second phase (*Identifying intervention options*) is based on selecting appropriate intervention functions, i.e., broad categories by which an intervention can change behaviour (e.g., education, persuasion, training, etc). It also includes choosing policy categories, such as guidelines, fiscal measures, or regulations, that may support these functions. The third phase (*Identifying BCT content and implementation options*) focuses on selecting appropriate Behaviour Change Techniques (BCTs). The BCTs support modifying determinants of behaviour and aid in behaviour change. Michie et al. (2013) developed the taxonomy of ninety-three BCTs, which are intended to be selected according to the appropriate psychological needs of the users. Usually, multiple BCTs are combined to support the behaviour change process. The application of BCTs must be explicitly observable in the intervention and described in enough detail so that researchers can replicate them (Michie et al., 2015). Examples of BCTs include *self-monitoring*, *feedback on behaviour*, *goal-setting*, *instruction on how to perform behaviour*, and *social support*. The Taxonomy of BCTs provides a name, definition and an example of BCTs.

The COM-B model integrates multiple theoretical determinants of behaviour from commonly used behaviour change theories into a set of clear, explainable categories (as shown in Table 1). This simplification enables intervention designers to consider

a wide range of behavioural determinants while maintaining conceptual clarity. This contrasts with other theories, such as the theory of planned behaviour (Ajzen, 1991), which focuses primarily on intention formation, and self-determination theory, which emphasises intrinsic motivation and autonomy, and addresses only a limited subset of behavioural determinants. The Behaviour Change Wheel (BCW) extends COM-B by linking determinants influencing behaviour with intervention functions and BCTs, providing a systematic process for selecting BCTs that specifically target those determinants. This structured linkage ensures that interventions are theoretically grounded and that the chosen techniques directly address key behavioural determinants, rather than being selected on an ad hoc or intuitive basis. This explicit linkage between behavioural determinants and BCTs is not offered by other behaviour change theories, which can make their practical application challenging, particularly for designers or practitioners without a background in behavioural science. BCW offers actionable steps, making it an invaluable tool for designing interventions that can be both broad in scope and tailored to specific contexts (Halonen, 2024).

Given this background, *intervention design* establishes the foundation for behaviour change interventions by identifying determinants and selecting suitable techniques. Behavioural psychology offers detailed guidance on behaviour change techniques and related behaviour change theories.

DBCIs have emerged as a new modality for delivering behaviour change interventions using mobile/web-based, wearables and social media applications. BCTs are operationalised and implemented via various digital features, such as reminders, rewards, and real-time feedback to encourage forming healthy behaviour in DBCIs. The shift from face-to-face to digital interventions adds complexity, including technology-mediated interactions, and variability in how digital platforms are accessed and used. User preferences, needs, and contexts shape these user interactions with the digital products. Thus, BCTs must be carefully operationalised in DBCIs to ensure both theoretical rigour and practical usefulness according to individual users' unique needs and contexts. Given the complexities introduced by digital products, a more nuanced approach to designing DBCIs is required to seamlessly integrate insights from behavioural change theories with the unique challenges of technology-mediated interactions. At this point, interaction design plays a significant role. While behavioural science provides the theoretical foundation for behaviour change interventions, *interaction design* ensures that user interactions with the DBCIs are carefully designed to support behaviour change. Below is an overview of various *interaction design* approaches and methods used to design digital products.

1.2. INTERACTION DESIGN FOR HEALTH DIGITAL BEHAVIOUR CHANGE INTERVENTIONS

Interaction design aims to define the behaviour of products and systems in response to their users to facilitate meaningful user interactions (Cooper et al., 2014; Jones & Marsden, 2006; Saffer, 2009). *Interaction design* is about “designing interactive products to support people in their everyday and working lives” (Preece et al., 2015, p. 6).

Popular *interaction design approaches*, such as System-Centred Design, Activity-Centred Design, Creator-Centred Design, User-Centred Design, and Goal-Directed Design (GDD), provide a well-defined sequence of phases that structure the overall design process. Each phase employs various methods, such as interviews, observations, personas, and scenarios, to support data collection, synthesis, ideation, and evaluation. This enables designers to systematically progress from understanding users to developing and refining design solutions (Saffer, 2009; Wei & Xing, 2010; Williams, 2009). Based on the situation, the designers can select one or a combination of approaches and methods for their design needs.

User-Centred Design is a widely used approach, and it focuses on user needs in the design process. It involves gathering user requirements, creating a user flow of tasks and decisions, creating prototypes, and evaluating and iterating the design solution. It focuses on understanding user needs, designing based on identified needs, evaluating the design with users and revising it if needed (Saffer, 2009; Williams, 2009). Designers conduct extensive research to understand users’ needs, behaviours, and contexts from the beginning of the design process. It allows designers to focus on user needs and preferences rather than design according to their preferences. The designer then determines the tasks and means necessary to achieve those goals, always considering the users’ needs and preferences (Saffer, 2009; Wei & Xing, 2010; Williams, 2009).

Goal-Directed Design (GDD) further extends User-centred design by focusing explicitly on users’ goals (Wei & Xing, 2010). GDD structures the design process around user goals, ensuring that every design decision is purposeful and aligned with helping users accomplish their goals. This alignment is particularly critical in the context of DBCIs, where interventions must be tailored to users’ motivations, preferences, and contextual constraints to support sustained engagement and support behaviour change. GDD offers a systematic process for transforming user insights into actionable design specifications that could support the design of interventions that are both goal-directed and contextually relevant. GDD consists of five phases (Figure 3).



Figure 3. Goal-Directed Design Approach of Interaction Design (Paper I)

GDD begins with understanding users’ goals, needs, attitudes, and the social and environmental context relevant to the future design (*I. User Research Phase*). It focuses on understanding the specific goals that users try to achieve with a product. Various user research methods, such as observations, contextual inquiry, interviews and focus groups, are used to understand their needs and define user goals. Interaction designers commonly use focus groups and interviews to explore when, why, and how the product fits into users’ lives or work processes (Cooper et al., 2014; Sharp et al., 2019), and provide an understanding of the topic in terms of the general agreement (W. Stewart et al., 2007). Focus groups help to understand how and why specific points and ideas are accepted or rejected based on the different viewpoints of the focus group participants. The outcome of *user research* activities should help identify user behavioural patterns that indicate goals and motivations (specific and general outcomes of using the product).

Next, the data gathered from user research is used to develop different representative and descriptive models of users by grouping people according to their shared characteristics, such as behavioural patterns (*II. Modelling Users Phase*). These models are also referred to as user personas. User persona guides the design process by serving as a reference point that helps designers make decisions aligned with user goals and challenges, ensuring iterative designs remain focused on user needs and reducing the risk of overlooking them (Cooper et al., 2014; Miaskiewicz et al., 2009; Pruitt & Grudin, 2003). User personas also foster empathy and improve communication within teams (Dahiya & kumar, 2018; Salminen et al., 2022). This ensures design decisions are based on real user needs rather than assumptions (Massanari, 2010; Miaskiewicz et al., 2009). Emmanuel & Polito (2022) mention that personas should be based on interviews, research, and data from actual user group representatives, with rigorous participant selection similar to scientific research.

User persona also represents user segments (an approach for differentiating user groups based on demographics or behavioural attributes). Segmentation helps identify subgroups within a larger population that are similar based on similar determinants influencing behaviour, response patterns or goals (Slater, 1996). Segmentation leads to a deeper understanding of the user by identifying the user segment’s preferences, needs, and wants. This helps in selecting the best design target audience and avoiding “designing for all” (Cougnon & Anciaux, 2024; Kitunen et al., 2025). The target segmentation approach has been widely used in public health interventions by health educators and health behaviour change researchers (Forthofer & Bryant, 2000; Slater, 1996; Smith, 2017). A user persona usually consists of a

persona name, a representative image, demographic variables, habits and routines, goals and preferences.

The next phase involves developing scenarios (*ideal user interactions with the product*) and identifying user requirements for each persona (*III. Requirement Phase*). It is intended to help to define what a product should be and what products should do. The *framework phase* defines the digital product's interaction framework, including the form factor, posture, data and functional elements, and interaction framework (*IV. Framework Definition Phase*). Lastly, the *refinement phase* involves the product's form and behaviour and translating the product into high-resolution screens.

Designers use various pre-defined *tools* (guides, templates, design patterns) that support the application of methods. For example, pre-defined topic guides facilitate the process of conducting focus groups and interviews (Krueger & Casey, 2014). Templates are pre-designed layouts that allow designers to systematically capture user characteristics and behaviour while focusing on content rather than reinventing formats, and ensuring consistency. A user persona template allows designers to systematically capture key user characteristics, needs, and behaviour patterns (Goodwin, 2009). Design patterns provide reusable, evidence-based solutions to common interaction problems, guiding designers on best practices while remaining flexible for different implementations (Cooper et al., 2014; Seffah, 2010; Tidwell et al., 2010).

Interaction designers are proficient in various design approaches and methods; they often lack in-depth knowledge of behaviour change processes and theories, which limits their ability to integrate these theories into the design process (Konstanti et al., 2022). Studies indicate a lack of practical and actionable guidelines for interaction designers to use theories for designing DBCIs (Klonoff, 2019; Sediva et al., 2022, 2022; Voorheis et al., 2023). Lastly, the current theoretical knowledge of BCTs lacks comprehensive practical guidelines on operationalising BCTs in DBCIs (Konstanti et al., 2022; Michie & Prestwich, 2010; Truelove et al., 2020).

The current work is focused on enabling interaction designers to design behaviour change theory-based DBCIs. It is assumed that supporting interaction designers with tools for designing behaviour change theory-based DBCIs can bridge the gap between the two practices. The next section will highlight the existing work on combining *intervention design* and *interaction design*, as well as the challenges and limitations.

2. RELATED WORK: CHALLENGES AND GAPS

The design of DBCIs is an inherently complex process that demands a thorough understanding of behaviour change theories and interaction design. Thomson et al. (2016) highlight that DBCIs (applications) have been designed and developed without the necessary foundation of expert knowledge or experience. Morrison (2015) argues that too little attention has been paid to how theory can be used to guide the design of practical features in DBCIs. Truelove et al. (2020) point out that although the BCW framework is extremely valuable in designing health behaviour change interventions, it does not provide guidance on how to translate BCTs into app features, largely due to the infancy of the mHealth field. Colusso et al. (2018) mention that academic findings are presented in ways that are difficult for designers to understand and apply in real settings.

Eight frameworks that guide the design of DBCIs for health were reviewed, for understanding existing guidelines and processes for designing and evaluating DBCIs, and the identification of critical gaps (*Paper I*). In *Paper I*, given the methodological nature and focus on proposing specific methods for every stage of the design process, Goal-Directed Design (GDD) was selected as the most suitable reference model for mapping existing designing DBCIs frameworks. Results highlighted that prototyping and usability testing are commonly mentioned phases in frameworks. Prototyping and usability testing are essential for understanding how users will use the product, but they do not help to understand users' needs and goals and why users behave in specific ways. Few frameworks (Lisowska et al., 2023; World Health Organization, 2020) mention the use of user persona, but they do not provide specific guidance on designing personas tailored for DBCIs (*Paper I*).

The reviewed frameworks largely treat intervention and *interaction design* as sequential processes, with *intervention design* preceding *interaction design*. However, they do not explain how insights from *intervention design* can be integrated into *interaction design* methods (Table 2). The absence of clear guidelines for designers can lead to knowledge and translational gaps between intervention and interaction design. Literature has highlighted that designers do not have specific knowledge about behaviour change theories and how insights from *intervention design* can be translated into the design of DBCIs (Colusso et al., 2018; Morrison, 2015; Thomson et al., 2016). Interaction designers can work in a team with or without a behaviour change expert. The sequential and isolated nature of traditional approaches can result in either a lack of application of theories due to interaction designers' limited knowledge of behaviour change theories and processes, or a lack of multi-disciplinary collaboration necessary for designing DBCIs. Behaviour change experts and interaction designers may work independently, leading to a lack of communication and collaboration. Without collaboration, crucial nuances in how users interact with the intervention and respond to BCTs may be overlooked, resulting in less effective outcomes.

Table 2. Mapping Of Frameworks For Designing DBCIS with Goal-Directed Design (Paper I)

Design	Phase	Methods	Frameworks for Designing DBCIs for Health Behaviour Change								
			Mummah et al. (2016)	Lisowska et al. (2023)	Wang et al. (2019)	World Health Organization (2020)	Mohr et al. (2014)	Young (2020)	Kowatsch et al. (2019)	Sucala et al. (2020)	
Intervention Design	Theory based Intervention		Described	Described	Described	Described	Described	Described	Described	Described	
	Research	User Research				Described				Non-Described	
	Modelling	Persona		Non-Described		Non-Described					
	Requirements	Scenario		Non-Described							
	Framework	Requirements									
		Defining form, factor posture & Input methods									
		Determine functional groups and hierarchy									
		Sketch the interaction framework		Non-Described							Non-Described
	Refinement	Construct key path scenarios					Non-described				
		Check designs with validation Scenarios									
Developing high resolution screen			Described								
Usability testing			Non-Described	Non-Described	Non-Described	Non-Described	Non-Described	Non-Described	Non-Described	Non-Described	
Support	Support										

Note. If the descriptions is presented with enough elaboration to be mapped as Interaction design methods was marked as Described, However, if only Interaction design method is named without enough elaboration to be mapped as IxD methods was marked as Non- Described.

This highlights a knowledge and translational gap in interaction design practice, where designers need better guidance on effectively using theory when designing DBCIs for health (Research Gap I).

Colusso et al. (2018) argues that tools supporting the integration of theories in the design process should not disrupt designers' thinking and workflow. To reflect on the limitations of regular tools for designing DBCIs, a graduate-level course, "*Designing Digital Products for Behaviour Change*", was developed in 2020. This course provided a valuable opportunity for continuous iterative development of the current methodology and critical reflection on the limitations of existing tools for designing DBCIs for health.

It was observed that the regular predefined tools used to support *interaction design* methods often do not help the designer capture and understand user needs and goals related to behaviour change. Students often struggle to ensure that interview or focus group questions comprehensively cover the key components of the COM-B model—Capability, Opportunity, and Motivation. Instead, questions tend to focus narrowly on specific domains, leading to missed opportunities to identify key determinants of behaviour. Literature review (*Paper II-Section 2*) highlighted that non-theory-based topic guides helped elicit user preferences and features for DBCIS, but did not explore the specific behavioural determinants (e.g., motivation, emotions, beliefs, skills) needed to design theory-based DBCIs. This highlights the need for structured topic guides to assist designers in conducting theory-based interviews/focus groups.

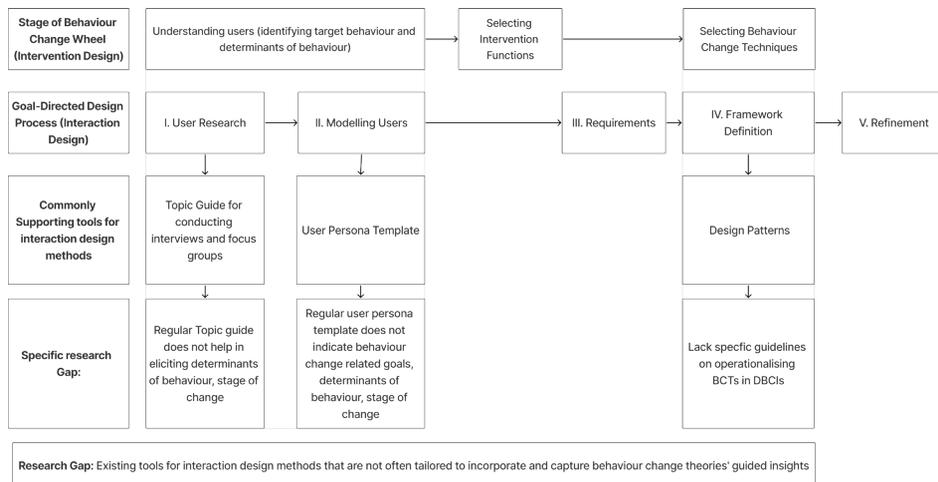
Similarly, the regular persona template does not provide specific sections to mention key determinants of behaviour or stages of change (*Paper III-Table I*). Some studies developed user personas that do not clearly indicate key determinants of behaviour and specific behaviour change goals, and used different ways of reporting them (Bhattacharyya et al., 2019; Monteiro-Guerra et al., 2017). Thus, more context-specific tools to help capture behaviour change-specific nuances are needed to support interaction designers. Lárusdóttir et al. (2022) proposed a contextual user persona method based on theories on the health work environment to help software developers understand the complexity of the digital work environment. Ferreira et al. (2017) proposed the technique to design a user persona, specifying who will use the product, characteristics of the persona's routines and environments, context, previous technology experiences, problems and needs, and existing solutions.

It was observed that interaction designers struggle to operationalise BCTs in DBCIs. The current theoretical knowledge of BCTs lacks practical guidelines on operationalising BCTs in DBCIs (Konstanti et al., 2022; Michie & Prestwich, 2010; Truelove et al., 2020). It is reported that the adoption and application of BCTs are fragmented, selected, and combined on an ad-hoc basis for designing DBCIs. Studies have found a disparity between the intended and selected BCT, and the content of the BCTs does not match the mentioned BCT (Conroy et al., 2014; Cowan et al., 2013; Dunn et al., 2018; Farhat-ul-Ain et al., 2022; Fulton et al., 2018; Lyons et al.,

2014; Morrissey et al., 2016; Simeon et al., 2020; Thomson et al., 2016). In some cases, the techniques used could not be coded within the existing taxonomy at all, indicating that BCTs were not operationalised correctly (*Paper IV*). A more practical and solution-oriented approach is needed to guide designers in operationalising and implementing BCTS in DBCIS. Previously, Konstanti et al. (2022) developed “Behaviour Change Strategy Cards” to allow designers to select specific techniques according to the stage of change. Thus, we must adapt tools to enable designers to integrate theory within their regular design practices and methods.

This lack of specific understanding and actionable tools leads to inadequate support for interaction designers, as they are not supported by enough information to design DBCIs for health. This highlights a gap in *existing tools for interaction design methods that are not often tailored to incorporate and capture behaviour change theories’ guided insights* (Table 3).

Table 3. Identified Research Gap



These research gaps highlight the need for a more integrated approach, enabling designers to apply behaviour change theories in designing DBCIs for health. One possible solution is to shape the existing tools to integrate behaviour change theory-based insights, which could help bridge the translational gap between intervention and *interaction design*. It is important to note that interaction designers often work in multidisciplinary teams without behaviour change experts, which means they may need to apply theory-informed approaches on their own. Structured, theory-based tools are therefore essential. They can guide designers to apply behavioural insights systematically when working independently and improve collaboration by providing a shared language and framework for teams.

3. PROBLEM STATEMENT, HYPOTHESIS AND RESEARCH QUESTIONS

One fundamental goal of such *interaction design* approaches as User-Centred Design and Goal-Directed Design is to understand users' needs and desires in detail to be used as a basis for designing solutions that are capable of addressing these specific needs (Cooper et al., 2014; Still & Crane, 2017; Stolterman & Wiberg, 2010). As mentioned above, designing for DBCIS for health requires more specific information, such as determinants of behaviour and stages of behavioural change, to ensure that the intervention can effectively target users' needs and support long-term behavioural change. The regular tools that facilitate interaction designers in understanding user needs, such as a user persona template, are not tailored appropriately to capture behaviour change-related insights. As a result, interaction designers struggle to identify the specific needs, barriers, and facilitators of behaviour change, making it challenging to make design-related decisions. Furthermore, interaction designers lack supportive knowledge on operationalising selected BCTs in digital contexts (Morrison, 2015; Truelove et al., 2020). Consequently, DBCIs may not be fully exploited in terms of their potential based on behaviour change theories, and the resulting designs may lack the necessary depth and fail to achieve the desired behaviour change goals. Thus, there is a need for an approach that can support *interaction design* in utilising behaviour change theory and shape *interaction design* tools and templates that can help design theory-based DCBIs for health.

The current research aims to develop an approach for integrating behaviour change theory with *interaction design* methods for designing DBCIs for health. It aims to refine tools for understanding user behaviour change-related needs and operationalising BCTs in DBCIs for health. In this research, the DHBC-Toolkit (Digital Health Behaviour Change Toolkit) is developed as a methodological tool to support the integration of behaviour change theory with *interaction design* methods in the design of DBCIs for health. To address the above-mentioned gaps, this dissertation is based on the primary research hypothesis: Integrating behaviour change theory into *interaction design* methods can help interaction designers make theory-informed decisions to support behaviour change. This leads to the research question: How can interaction design tools be shaped with behaviour change theories to equip designers in understanding behaviour change-specific needs and operationalising behaviour change techniques in DBCIs? The main research question is then divided into sub-questions explored further in research papers (Table 4 Table 4. Main Research Questions, Research Objective, and Paper-Specific Research Questions).

Table 4. Main Research Questions, Research Objective, and Paper-Specific Research Questions

Research Questions Raised in the Thesis	Addressing Articles	Paper -Specific Research Questions
Main research question: <i>How can interaction design tools be shaped with behaviour change theories to equip designers to design DBCIs for health?</i> (Overarching question)		
(a)	What are the existing frameworks for designing digital behaviour change interventions for health?	Paper I RQ 1. How and to what extent are interaction and intervention design integrated into the existing DBCI frameworks?
(b)	How can behaviour change models be used to enrich the interaction design topic guide for user research methods (interviews/focus groups) for health?	Paper II RQ 1. How can behaviour change theories be integrated into a topic guide for interaction designers to understand user behaviour change-related needs when conducting user research for designing DBCIs? RQ 2. To what extent is a theory-enriched user research topic Guide template helpful in identifying the needs of children with Type I diabetes (case study)?
(c)	How can existing templates used for user persona be shaped to enable interaction designers to capture user health behaviour change-related needs?	Paper III RQ 1. How to integrate behaviour change models into regular user persona descriptions? RQ 2. To what extent can theory-enriched user persona template and descriptions be helpful in identifying user segments, goals, needs, and behavioural patterns compared to a regular user persona?
(d)	How can design patterns be developed to help designers operationalise behaviour change techniques in digital behaviour change interventions?	Paper IV RQ 1: What strategies are mostly used in the existing DBCI studies to deliver the specific behaviour change techniques in digital interventions? Paper V RQ 1: How can design patterns be developed to help designers to operationalise behaviour change techniques in digital behaviour change interventions? RQ 2: To what extent do interaction design experts perceive proposed design patterns for BCTs as understandable, helpful and acceptable?

4. RESEARCH OBJECTIVES

The primary objective of the current thesis is to *shape and enrich existing tools in a way that can facilitate the design of DBCIs for health by integrating behaviour change theories into interaction design methods*. The sub-objectives of the thesis are presented below:

Sub-Objective 1. To refine existing tools that support user research and user persona

This research objective is focused on enriching the existing tools and templates regularly used for user research and persona with behaviour change theories. It first aims to provide a set of generalisable questions based on behaviour change theories for conducting user research (focus groups or interviews). Secondly, it aims to enrich regular user persona templates and descriptions, allowing designers to capture behaviour change-related insights from user research.

Sub-Objective 2. To develop design patterns for behaviour change techniques

This research objective is to develop a collection of design patterns that can facilitate designers' efficient operationalisation of behaviour change techniques in DBCIs. It aims to create reusable solutions for designers to use across contexts in their digital behaviour change applications. By offering a blueprint for integrating BCTs, these patterns will help design better, theoretically grounded interventions that can improve the overall design of DBCIs.

Sub-Objective 3. To conduct expert evaluations of refined tools and design patterns.

The objective is to conduct expert evaluations to evaluate refined templates and design patterns. The evaluation included collecting feedback from these experts to assess the refined tools' practicality, acceptability, and potential usefulness when designing DBCIs for health. This feedback is crucial for refining and enhancing tools and patterns so that they can help interaction designers and support them in designing for DBCIs.

5. METHODOLOGY

The approach of this research work can be framed as *research for design* and *through design* (Figure 4). It combines both approaches in a way that: 1) the current work aims to enhance the practice of *interaction design* in the specific context of designing for behaviour change (research for design), and 2) knowledge generation occurs through the process of ideation, solution generation, iteration and refinement of proposed solutions, and reflection (research through design).

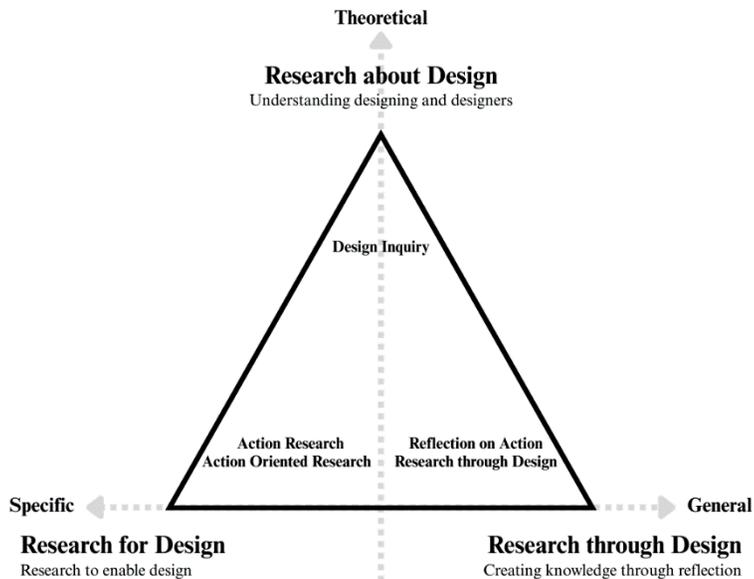


Figure 4. Research for Design and Research through Design (adapted from (Tieben, 2015))

Downton (2003) mentions **research for design** as “research to enable design”. It provides information designers can use to create digital products for specific contexts. The research-for-design approach is undertaken to achieve the overarching goal of helping future designers by supporting them with pre-defined tools for designing better DBCIs for health, and this is accomplished via **research through design**. Research through design produces knowledge referred to as a *theory on design*. It involves producing conceptual frameworks, guidelines, and design implications (Zimmerman et al., 2010). By adopting the role of a researcher (research community), the current work focuses on producing “research artefacts” (Zimmerman et al., 2007). It states that research artefacts involve contributions such as “integrations of theory, technology, user needs and context, not merely the refinement of products. In this research work, results take the form of a template-based toolkit to help designers (practice community) improve the design of DBCIs and observe the value

of the proposed research artefacts. The tools were developed through an iterative design, reflection, and evaluation process. The course “*Designing Digital Products for Behaviour Change*” supported the reflective process and provided a valuable opportunity for critical reflection and refinement of the proposed tools. I observed how tools functioned in the specific context (design for behaviour change) and refined them in various iterations.

The current research followed a sixth-phase iterative design and development approach (J. Ellis & Levy, 2010). Below is an overview of the methodological process in Figure 5.

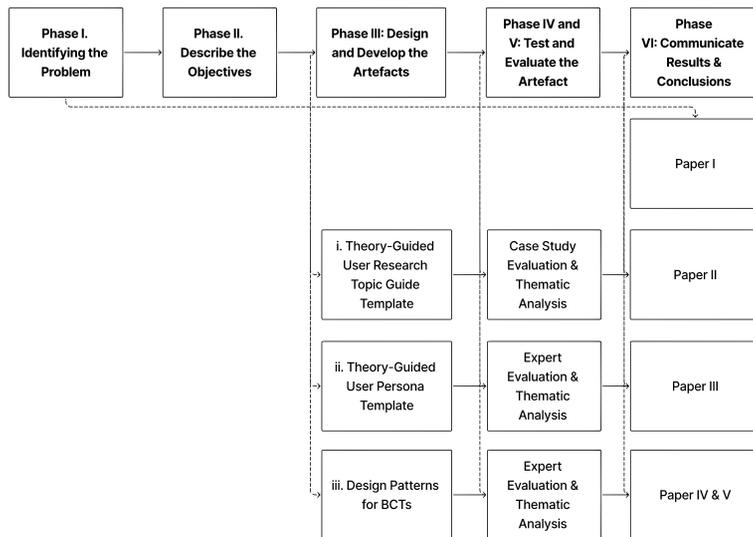


Figure 5. Overall Methodological Process for Designing and Evaluating Research Artefacts (J. Ellis & Levy, 2010).

The first phase (*Phase I: Identifying the problem*) is focused on reviewing the relevant literature and exploring the gaps in literature and practice. The second phase (describing the objective) is focused on defining the hypothesis, research questions, and study objectives. Phases III–V focused on iterative design and evaluation of the research artefacts. Phase VI presented and published the artefacts and evaluation results. A detailed explanation of each phase is given below.

5.1. IDENTIFYING THE PROBLEM AND DESCRIBING THE STUDY OBJECTIVES (PHASES I AND II)

During the first phase of the study, a literature review on existing frameworks for designing DBCIs was conducted to explore how interaction and *intervention design* methods are combined into these frameworks. Databases, including Google Scholar,

ACM, IEEE, and PubMed, were searched for published frameworks specific to designing DBCIs for health. Frameworks were excluded if they did not specifically focus on designing DBCIs for health. Overall, eight frameworks were included in the review. The literature review results (*Paper I*) helped identify key gaps in the existing literature, which are discussed in detail in Section 3.

Paper II highlighted that *interaction design* employs various qualitative methods, such as interviews, focus groups, observation, and ethnographic studies, to understand user needs. Conventional user research methods such as, interviews and focus groups often lack a direct focus on uncovering users' specific needs related to behaviour change. The conventional approach overlooks understanding the key determinants that influence individual behaviour and hinder behaviour change.

Paper III highlighted the challenges of using regular persona templates and descriptions for designing DBCIs. These limitations primarily reflect the absence of clear specification regarding behaviour change goals, behaviour-related needs, determinants of behaviour, and the stages of change of individuals.

Paper IV–V highlighted the lack of specific practical guidelines for operationalising BCTs in DBCIs. The adoption and application of BCTs are fragmented, selected, and combined on an ad-hoc basis for designing DBCIs. Sections 4 and 5 defined the study problem and objectives based on the research gap.

A *Digital Health Behaviour Change (DHBC) toolkit for Interaction Designers* was developed to achieve the research objectives, comprising three key artefacts (contributions) that were systematically designed, refined, and evaluated throughout the study.

- A comprehensive *theory-enriched user research topic guide* (Artefact I) to aid interaction designers in understanding the specific determinants influencing behaviour (*Paper II*);
- A *theory-enriched user persona guide* (Artefact II) that supports interaction designers in capturing insights from theory-based user research and in modelling user characteristics for the design of Digital Behaviour Change Interventions (*Paper III*).
- A collection of *design patterns for BCTs* (Artefact III) to help interaction designers operationalise BCTs within DBCIs (*Paper IV–V*).

The artefacts (I, II, III) were designed and developed through an iterative process and further evaluated using various methods. The detailed design and evaluation process for each artefact is presented below.

5.2. DESIGN, EVALUATION AND COMMUNICATION OF THE ARTEFACTS (PHASES III-VI)

The design and evaluation process for each artefact is presented in detail below.

5.2.1. Design and Evaluation of the Theory-Enriched User Research Topic Guide Template for designing DBCIs

The overall design and evaluation process of *the theory-enriched user research topic guide template* (Artefact I) is presented in Figure 6.

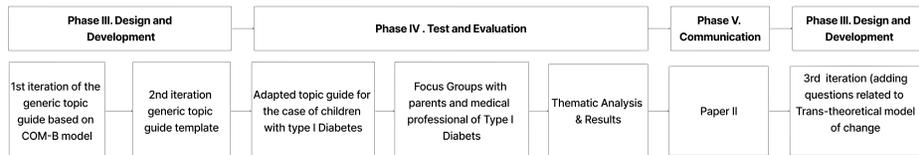


Figure 6. *The Overall Process for Designing and Evaluating Theory-Enriched User Research Topic Guide Template*

The *theory-enriched user research topic guide template* was developed in three major iterations. The COM-B model was selected as it combined various behaviour change theories, aiding designers in gaining a more holistic understanding of the users, identifying the challenges and barriers related explicitly to behaviour change. Initially, during the course activities, each group of students in the course was assigned the task of developing interview questions aimed at understanding user needs in the context of behaviour change. Significant variability in the question was reflected in the topic guides. For example, topic guides did not adequately cover all the necessary domains and sub-domains of the COM-B model. This highlighted the need for a more structured and theoretically grounded topic guide to better support behaviour change-specific user research. Thus, in the *first iteration*, only COM-B-based questions were developed, improved, and simplified through repeated review and reflection processes during various course iterations, making them more understandable for designers.

The *theory-enriched user research topic guide template* (Paper II-Table 2) was formed in the second iteration to help designers easily adapt questions to specific health behaviour. It provided structured yet flexible questions for understanding users' behaviour change-related needs. The purpose of the questions was added to the template. Guidelines for adapting and analysing results were provided (*Paper II*). The evaluation of these questions was made through a case study approach. It was important to evaluate and understand to what extent the *theory-enriched user research topic guide template* is adaptable and generates data that could be useful in designing DBCIs for health. The proposed User Research Topic Guide Template was evaluated through a case study (*Paper II*). The case study method helped evaluate the

proposed topic guide in a real healthcare setting, providing insights into its practical applicability in real user research cases.

For this purpose, the case of understanding the needs of children with Type I diabetes was selected. Children with Type I diabetes have to adhere to a complex treatment routine. Adherence significantly due to the transition from parental care to self-care and puberty. Overall, six focus groups were conducted with parents and medical professionals dealing with children (11–18 years) diagnosed with Type I Diabetes. Ethical consent was obtained to conduct focus groups with parents and children with Type I diabetes to protect participants’ rights and well-being throughout the research process. The proposed *theory-enriched user research topic guide template* was adapted to conduct focus groups with parents and medical professionals dealing with Type I diabetes (*Paper II*–presented in Table 2).

The deductive framework approach was applied to analyse the qualitative data (Gale et al., 2013). The first stage involved thematic analysis of the qualitative data using the Braun and Clarke approach (Braun & Clarke, 2006). The second stage included mapping generated themes onto COM-B components. For example, forgetting to take medications can be linked with psychological capability. The results of the evaluation are presented in Section 7.1. *Paper II* presents the *theory-enriched user research topic guide template* (*Paper II*–Table 2) and evaluation results.

In the third iteration, questions related to the Transtheoretical Model of Change were integrated into the topic guide to help designers understand the current stage of change while designing DBCIs for health. These questions were added in the final version of the toolkit (more details in Section 7.1). This iterative refinement process ensured that the final topic guide template was theoretically grounded and practically helpful in gathering and identifying users’ theory-based behaviour change needs.

5.2.2. Design and Evaluation of Theory-Enriched User Persona Guide

The overall design and evaluation process of the *theory-enriched user persona guide* is presented in Figure 7.

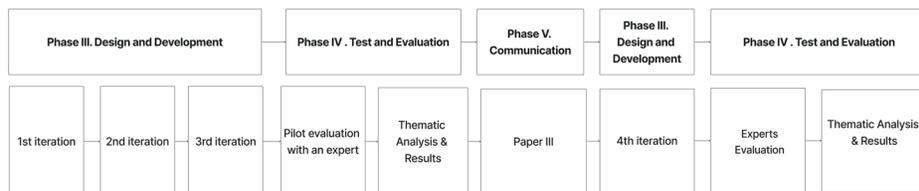


Figure 7. *The Overall Process for Designing and Evaluating a Theory-Enriched User Persona Template*

Overall, the *theory-enriched user persona template* was designed in four iterations. This iterative process was supported by the course “Designing Digital Products for Behaviour Change”. In the first iteration, a regular user persona was used (*Paper III*–Table 1). I reflected that regular user persona templates do not allow for capturing behaviour change-specific goals, user behaviour change-related specific needs (determinants influencing behaviours), and stage of change.

In the second iteration, the Transtheoretical Model of Change and the COM-B model were integrated into the *theory-enriched user persona template* (Appendix 2). The following enhancements were made to the template:

- i. The segment section in the User Persona template was used to identify the stage of change (based on the transtheoretical change model) and to differentiate user groups based on their stages.
- ii. A section related to “COM-B patterns” was added to mention individuals’ user behaviour change-related specific needs (determinants of behaviour).
- iii. Other sections of the template include goals and needs, habits and routines, and challenges and barriers specified in the context of behaviour change

This revised *theory-enriched user persona template*, with specific sections, helped identify users’ stages of change, allowing for better segmentation of others. Individuals in different stages of change are considered to be in different personas’ segments. The sections related to the “COM-B pattern” allowed for the capture of determinants influencing user behaviour. However, the *goals and needs* sections in the template remained somewhat generic and lacked sufficient specificity regarding what should be captured in this section, leading to ambiguity in how it should be completed. Additionally, the concept-related “challenges and barriers” overlapped with the COM-B patterns, indicating a need for further refinement of the *theory-enriched user persona template*.

In the third iteration, further improvements were made to the *theory-enriched user persona template* (*Paper III*–Table 2), which includes:

- i. The Theory-Enriched User Persona Template divides goals into three sections: goals related to behaviour change, target behaviour for change, and specification of the target behaviour.
 - a. *Goals related to behaviour change* represent the broader outcomes that the intervention aims to achieve (for example, going for regular physical activity).
 - b. The *target behaviour* defines the specific behaviour the intervention seeks to influence (for example, going for a walk daily), while the specification of the target behaviour presents more details about the selected target behaviour, for example, when to perform the target behaviour and with whom to perform (for example, going for walk at least 30 minutes in the evening).

- iii. The section on challenges and barriers to behaviour change was renamed COM-B-based challenges and barriers, and the previously added section on COM-B patterns was removed.

A pilot evaluation study was conducted using the template presented in Section 7.2, during which one expert carried out the evaluation. The expert had extensive expertise in designing methods and tools for designers. A semi-structured interview was conducted to explore how adding sections specific to behaviour change helps understand user segments, behaviour change-related goals and COM-B-based challenges and barriers. Table 5 mentions the questions used for expert evaluation.

Table 5. Semi-Structured Interview Questions for Expert Evaluation (extracted from *Paper III*)

Interview Questions	
1	Do you consider yourself knowledgeable about theories in behaviour change?
2	Does the theory-enriched user Persona help better identify user segments than a typical Persona?
3	Does the theory-enriched user Persona help better understand behaviour change goals and possible outcomes compared to the typical Persona?
4	To what extent does each user’s Persona highlight challenges and barriers specific to behaviour change?
5	Would you like to use this approach in case you need to design for behaviour change?

Based on the expert feedback, a *theory-enriched user persona guide* with more specific instructions was prepared (fourth iteration) and was evaluated by three practitioners-experts. One practitioner-expert had a background in designing DBCIs for health, while the other three had experience in designing User Personas in various practical settings. The *theory-enriched user persona guide* and questions for evaluation (Table 5) were sent to the practitioner-expert a week after the scheduled interview. This allowed practitioners to review the toolkit in-depth and provide feedback. Section 7.2 mentions the detailed results of the pilot and practitioner evaluations, as well as the final version of the *theory-enriched user persona guide*.

5.2.3. Design and Evaluating Patterns for Behaviour Change Techniques

The overall process for designing *design patterns for BCTs* is mentioned below and highlighted in Figure 8.

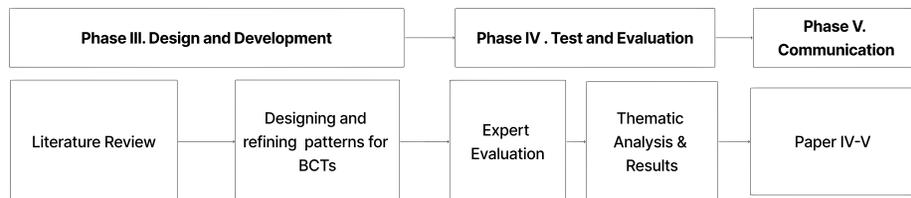


Figure 8. *The Process for Designing and Evaluating Design Patterns of BCTs*

Firstly, it was important to understand how BCTs are operationalised in DBCIs for health to design evidence-based *design patterns for BCTs*. For this purpose, a preliminary literature review of 35 studies was conducted. Information related to BCTs, mode of delivery, and targeted conditions was extracted and labelled using the Taxonomy of Behaviour Change (V1). All features mentioned in studies, such as reminders, were labelled with the most appropriate BCTs. In some cases, an adequate description was not mentioned, which was labelled as “not enough information to code”. Some studies utilised interventions that cannot be coded as BCTs and labelled “No BCT present”. The included studies ranged from 2013 to 2021. The results indicated the commonly used BCTs in DBCIs and how various BCTs were operationalised in the DBCIs for health (*Paper IV*–Table 2). Table 6 highlights methods used to operationalise six commonly applied BCTs in DBCIs.

Table 6. Six Commonly Used BCTs and Methods of Operationalising BCTs in DBCIs (Extracted from Paper V)

BCT name & Definition	Various methods of operationalised BCTs
Prompts and Cues	<ul style="list-style-type: none"> • Sending reminders/prompts to perform health-related activities through mobile applications, calendar-based systems, email/text messages (WhatsApp), prompting questions, and daily challenges. • Personalised reminders based on the users’ selected time/day.
Social Support (unspecified)	<ul style="list-style-type: none"> • Support and encouragement through apps, text messages, testimonials, WhatsApp groups, and community forums. • Phone calls for counselling by clinicians and counsellors • Clinicians or users were posting on Facebook or a team-based app.
Goal Setting (behaviour)	<ul style="list-style-type: none"> • Goal setting using in-app calculators, personalised goal setting, predetermined goals, and tweak suggestions. • Negotiating goals and developing plans using a virtual agent or digital health coach.
Self-monitoring of Behaviour	<ul style="list-style-type: none"> • User transfers data related to health goals in mobile applications. • Self-monitoring using wearables and building in-app tracking devices.
Instructions on how to perform a Behaviour	<ul style="list-style-type: none"> • Animated stories and text messages are sent to help users learn behaviours. • Mobile applications used to teach various behaviours, e.g., instructions on the type and duration of exercise, estimating food portions, etc.
Feedback on Behaviour	<ul style="list-style-type: none"> • Feedback using visual/graphical displays (bar chart, graphs, pie chart) via mobile applications and online systems. • Personalised online feedback sessions delivered by health coaches.

Secondly, Tidwell’s approach (2010) was adapted to develop the *design patterns for BCTs*. This approach was found to be more suitable for developing *design patterns for BCTs* because it contained a classification of interaction design patterns, a few examples, a clear structure, and an extensive explanation of why and how they can be utilised in the design. I expanded the typical structure by adding concepts “*Design Principle and Theory*” and “*BCTs combinations*”. *Design Principle and Theory* concept represents underlying theoretical constructs and mechanisms that influence behaviour in the case of specific BCT integration and, thus, may be used as a reference to the theory. *The concept of BCT combinations represents BCT relations according to taxonomy and provides examples of how they can be implemented in the interface in combination*. The adapted structure of Tidwell’s approach for *design patterns for BCTs* is presented in Table 7.

Table 7. Structure of Tidwell Design Pattern Adapted for Behaviour Change Techniques (Paper V)

Elements	Purpose
Pattern Name:	Define the pattern name
Code/BCT name (Group) in Taxonomy	BCT’s name and group are mentioned in the BCT Taxonomy
Illustrative example	Screenshots of the instantiated. In our case, it presents carefully selected images of BCTS operationalised in digital interventions.
What (Problem):	A short problem statement to specify the user needs for which BCT can be used.
Use when	Conditions in which patterns can be used.
How	Represents the solution in the pattern for the BCT.
Why	Provide the design rationale for BCT.
Design principles and theory	Establishes the link between pattern, behaviour change theory, and technique.
BCTs combinations:	Elaborate on how BCTs can be combined with other techniques.
In other collections:	Directs to similar patterns in other collections, potentially offering new insights or examples.

Design patterns were developed for the six commonly used BCTs following the structure mentioned in Table 7. The initial set of design patterns was developed and improved iteratively after discussion with the supervisor, ensuring they were theoretically sound and useful for designers. Finally, the refined design patterns were compiled into a comprehensive toolkit and further evaluated. The practitioner-expert evaluation was conducted to assess the design patterns’ understandability, helpfulness, and acceptability. Semi-structured questions were developed based on

a checklist and criteria mentioned by Wurhofer et al. (2009, 2010). Semi-structured interviews were conducted with four interaction design practitioners (Table 8).

Table 8. Semi-Structured Interview Questions for Expert Evaluation (Paper V)

Criteria	Interview Questions
Understandability	How clear and understandable are the descriptions in the elements and examples provided in the design patterns for behaviour change techniques? (Sub-questions focused on understanding overall comprehensibility, language, balance between concreteness and abstractness of the design and ambiguity in the design patterns)
Helpfulness	To what extent does the design pattern benefit you in facilitating your design process or addressing the design of specific behaviour change techniques? (Sub-questions focused on capturing relevant information, contribution to the development of improved designs for behaviour change interventions, and helpfulness in facilitating communication among designers, developers and researchers).
Overall Acceptability	Do you find yourself nodding in agreement as you read the pattern descriptions of BCTs, or does any design pattern description need to be improved? Considering your expertise and experience, how likely are you to incorporate these design patterns into your future projects?

Two practitioners had a theoretical understanding of behaviour change theories and techniques, while one also had a background in DBCIs for health. The other two practitioners needed to have a specific understanding of behaviour change theories, but they were aware of persuasive technologies and proficient in understanding design patterns. An example of a design pattern is presented in Section 7.3. Design Patterns are published in *Paper V*.

5.2.4. Development of DHBC toolkit

After each research artefact, a comprehensive **DHBC (Digital Health Behaviour Change)** toolkit was developed. This toolkit consolidates all the research artefacts into a cohesive structure, with tailored guidelines for each one that clearly outline when to use them, how to apply them, and how they interconnect within the design process.

6. RESULTS AND CONTRIBUTIONS

This section proposes an overview of the thesis contributions and discusses the findings. The main objective was to shape and enrich existing *interaction design* methods by systematically integrating behaviour change theories into existing interaction design tools. The thesis contributes five key outcomes across five research papers and the final DHBC-toolkit.

- First, it includes a review of existing frameworks for designing DBCIs to understand existing practices and identify gaps (Contribution 1). This is explained in Section 3.
- The second contribution presents a behaviour change *theory-enriched topic guide* for Interaction Designers to support user research for designing DBCI for health. Details of the topic guide and case study results are provided in Section 7.1.
- The third contribution presents a *theory-enriched user persona guide* for Interaction Designers aimed at helping designers incorporate specific behaviour change-related goals and COM-B-based barriers in a typical user persona template. The *theory-enriched user persona guide* and expert evaluation results are discussed in Section 7.2.
- The fourth contribution includes the development of *design patterns for BCT*. It involved mapping operationalised BCTs in DBCI with the taxonomy of behaviour change techniques. This provided the foundation for developing *design patterns for BCTs*, which is discussed in detail in Section 7.3.
- Finally, the fifth contribution is the development of a comprehensive DHBC Toolkit, which integrates all the above tools — *a theory-enriched user research topic guide, a theory-enriched user persona guide, and design patterns for BCTs* — into a cohesive resource for interaction designers working on behaviour change interventions. The DHBC toolkit is presented in Appendix 1.

6.1. BEHAVIOUR CHANGE THEORY-ENRICHED TOPIC GUIDE FOR INTERACTION DESIGNERS

Understanding user needs is the first phase in User-Centred and Goal-Directed Design methodologies. Various qualitative methods, such as interviews, focus groups, observation, and ethnographic studies, are used to understand user needs. The first contribution is based on proposing a template for conducting behaviour change-based interviews and focus groups. The work aims to empower interaction designers by providing theory-based questions (Table 9) that can be easily adapted to understand user determinants of behaviour in various contexts (specifically in healthcare). Each question directly relates to the COM-B components, sub-components and related TDF domains. For instance, psychological capability-related

questions will help elicit responses that will directly guide and help understand the psychological capability-related needs of the users. These questions are designed to be flexible and adaptable to different health behaviours. For instance, a question like “What kind of mental skills are required to [perform specific behaviour]?” can be applied differently to various activities like walking or eating healthily or counting calories. The questions in the *theory-enriched user research topic guide template* can be made suitable for addressing different target populations (*Paper II*).

Table 9. Selected Questions mentioned in Theory-Enriched User Research Topic Guide Template (Paper II)

	<p>Reflective Motivation</p> <ul style="list-style-type: none"> • How do you perceive the consequences of [performing specific behaviour]? • Can you describe any beliefs or attitudes that influence your decision-making regarding [performing specific behaviour]? • Do you intend to change your behaviour? • Are you optimistic about changing your behaviour? • Do you have specific goals for changing your behaviour? <p>To what extent is this behaviour accepted by your society (friends, family, employment)?</p>	<p>Intended to support understanding of beliefs about capability, consequences, intention to perform behaviour, goals, optimism, and identity that can influence behaviour.</p>
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It was important to evaluate the proposed topic guide template’s usefulness in generating data that could help design DBCIs for health, and to what extent it could be easily adapted. Six focus groups were conducted with parents and medical professionals dealing with children with Type I diabetes. The questions were adapted for this specific context, as mentioned in Table 3 (*Paper II*). Results indicated various behaviour change-related needs of the children and highlighted age-related differences in children’s skills, independence, and motivation to manage diabetes. Various behaviour change theory-based design implications (design hypotheses) for *interaction design* were derived based on the results presented in *Paper II*.

In addition to the questions presented in Table 2 (*Paper II*), in the second iteration, further questions were formulated based on the transtheoretical model of change (presented in Section 2.1) to help designers understand the specific stages of change (Prochaska & Velicer, 1997). These questions were not part of *Paper II* but are part of the final toolkit for designers. The questions are mentioned below in Table 10.

Table 10. Questions based on the Transtheoretical Model of Change

Questions based on the Transtheoretical Model of Change		
	<p>Pre-contemplation stage</p> <p>Can you describe your current thoughts and feelings about [target behaviour]? Are you considering making any changes to address [health behaviour]?</p>	Understanding the pre-contemplation stage
	<p>Contemplation stage</p> <p>Have you noticed any benefits or drawbacks associated with [target behaviour] that are influencing your decision-making process? What specific concerns or barriers are you facing in deciding whether or not to change [target behaviour]?</p>	Understanding more about the contemplation stage
	<p>Preparation stage</p> <p>Are you actively planning or preparing to adopt [health behaviour]? Can you discuss any specific steps or strategies you have in place to facilitate behaviour change?</p>	Preparation stage
	<p>Action stage</p> <p>Have you recently started engaging in [health behaviour]? Can you discuss any challenges or successes you have experienced since initiating this behaviour change?</p>	Action stage
	<p>Maintenance stage</p> <p>How do you plan to sustain [health behaviour] over the long term? Can you discuss any ongoing efforts or resources you utilise to maintain your behaviour change?</p>	Maintaining stage
	<p>Relapse stage</p> <p>What factors or triggers led to your relapse in [health behaviour]? What plans do you have to recover from this relapse and get back on track with your behaviour change goals?</p>	Relapse Stage

It is critical to note that, even though intervention designers also conduct qualitative studies to understand determinants of behaviour, conducting theory-based user research is essential for interaction designers to ensure the efficient translation of theoretical insights into the product’s design. It will help interaction designers and the overall design process in several ways.

- It will help designers better understand users’ behaviour change-related needs of the users and develop empathy.
- The results of theory-based interviews can easily be translated into practical design elements and linked directly to the users’ needs related to behaviour change.

- The iterative nature of the design process requires continuous feedback from users at various stages of product design. Theory-based interviews can facilitate this process.
- It facilitates communication between stakeholders, especially intervention and interaction designers. Collaboration among different teams can be enhanced when designers are directly involved in gathering behaviour change insights.

The final proposed *theory-enriched user research topic guide* is presented in Appendix 1-Section I. After understanding how aimed behaviour changes related to user needs, it is important to make these insights usable throughout the design process. User Persona is an important tool that helps to represent user needs, goals and challenges based on user research. Regular user persona templates are insufficient to capture user behaviour change-related needs (*Paper III*). Therefore, the next aim is to enrich the persona templates with behaviour change theories. The next contribution is focused on proposing a behaviour change *theory-enriched user persona template* for interaction designers.

6.2. BEHAVIOUR CHANGE THEORY-ENRICHED USER PERSONA GUIDE FOR INTERACTION DESIGNERS

Having enriching user research interviews and focus group methods with the COM-B model, capturing behaviour change-related needs and insights into a user persona is essential. Based on the iterative and reflective process on the limitations of the regular user persona, the author integrated the COM-B and Transtheoretical Model of Change in the regular user persona template presented in Table 11. This integration allowed us to understand the information mentioned below related to behaviour change.

- User segments based on a transtheoretical model of change. Users in similar stages can be grouped according to their current stage of change. It will enable designers to define user segments according to the user’s current behaviour change stage and plan interventions.
- Clear representation of behaviour change goals in the persona template. These components are structured and informed by the BCW (presented in Section 1.2–Table 1)(Michie, Atkins, et al., 2014) .
 - a. *Goals related to behaviour change* represent the broader outcomes that the intervention aims to achieve (for example, learning how to “close the laptop and stop working on time” to feel mentally and physically relaxed, or adopting a routine of regular exercise).
 - b. The *target behaviour* is the specific habit that the intervention is designed to change or support (for example, to develop a habit of stopping working when the work hours end).
 - c. The *specification of the target behaviour* presents more details about the selected target behaviour (for example, close all work-related

devices and apps, stop working after 6 p.m., stop thinking about it, mute WhatsApp notifications, and set up focus mode).

- Defining challenges and barriers based on the COM model to reflect and indicate determinants of behaviour will allow interaction designers to select behaviour change techniques according to challenges and barriers.

Table 11 presents an example of a User Persona built on a *theory-enriched user persona template*. The text in italics represents descriptions related to the behaviour change theory that are added to the regular template behaviour.

Table 11. An Example of User Persona Built on a Theory-Enriched User Persona Template (Paper III)

	<p>DEMOGRAPHICS: NAME: Anna; AGE: 29; GENDER: Female; LOCATION: Berlin; FAMILY STATUS: Long-term relationship without children; EDUCATION: Master’s degree; JOB TITLE: Marketing Specialist; INDUSTRY: IT.</p> <p>IN SEGMENT: <i>Contemplation Stage</i></p>
<p>Quote: “I want to return to my normal life and enjoy time away from work.”</p>	
<p>Bio: Anna is from Riga. She serves individuals employed in the IT sector as a freelance marketing specialist and delivers targeted marketing services to IT companies. She has to show a constant online presence to be competitive in the market among other marketing professionals. She wants to grow in her career, but having too much work prevents her from enjoying life and spending time with her partner, who has already begun to be distant from her. Feeling burnt out lately, Anna became concerned about her mental health and realised that the first thing she needed to do was to change her habits and routine. <i>Being a shy person, she doesn’t feel comfortable talking to her clients about the existing problem and the need for a change of her work schedule and routine.</i></p>	
<p>Habits and Routines related to Behaviour Change: Anna works more than 8 hours daily on her laptop, but when she is not at the desk, she continues on her smartphone. She has to show a constant online presence to be competitive in the market among other marketing professionals. She posts actively on social media because she shows examples and ideas of what her clients could do with their social media accounts. <i>She mainly uses WhatsApp to communicate with her clients and colleagues. She is always alert and never turns off notifications so she can read all messages immediately.</i></p>	
<p>Goals related to Behaviour Change: <i>Learn “how to close a laptop and stop working” on time to feel mentally and physically relaxed.</i></p>	
<p>Target behaviour: <i>To develop a habit of stopping working when the work hours end.</i></p>	
<p>Specification of Target Behaviour: <i>Close all work-related devices and apps, stop working after 6 p.m. and stop thinking about it, mute WhatsApp notifications, and set up focus mode.</i></p>	

<p>Dislikes, concerns, fears (-) related to Behaviour Change: Anna spends too much time working and misses her personal life; she doesn't want to become distant from her partner; she is afraid of not having a planned routine and time to do everything in high quality; <i>she feels burnout, and she is afraid of not being understood by her clients if she changes her routine and will be not available for a while.</i> Likes, interests, desires (+) related to Behaviour Change: She likes to spend time with her loved ones. Anna would like to have better time management and planning skills. Motivators: <i>Anna wants to find the right life-work balance to be productive and effective at work, but get more time for her personal life and take care of her mental health.</i></p>
<p>COM-B-based Challenges & Barriers Related to Behaviour Change: Psychological Capability: <i>She needs to increase her ability to plan her schedule and regular resting time.</i> Social Opportunity: <i>Her clients need to understand her need to be away from work (not being reachable for a while). She feels pressure from other marketing specialists and what they set as social norms.</i> Physical Opportunity: <i>She does not have specific technology/tools to help her manage her routine except the laptop and smartphone.</i> Reflective Motivation: <i>She believes that digital marketers should always be present and because of that she thinks she cannot just pause work and focus on her personal life and quit all work-related applications.</i> Automatic Motivation: <i>Anna always wants to check social media to respond to every message quickly, and because of that, even if she closes all work-related applications, she automatically/habitually checks them every 5 minutes and cannot relax.</i></p>
<p>Values: Kindness, integrity, loyalty, hard work, relationships.</p>
<p>Technology Preferences: She uses a laptop and phone every day. She works more than 8 hours daily with the laptop. In her work, as well as in her personal life, Anna mainly uses social media channels: LinkedIn, Instagram, Facebook, and Twitter.</p>

The expert in the design field evaluated the proposed *theory-enriched user persona template*. The expert's feedback highlighted the usefulness of theory-enriched user persona descriptions for designing behaviour change interventions in the health domain. The expert found the approach beneficial and emphasised the importance of making the descriptions more understandable and explicit for designers. Additionally, the expert suggested enhancing the template's visual appeal to make it more engaging and motivating for designers. The detailed results are presented in *Paper III*–Table 3.

Based on the initial expert evaluation, a *theory-enriched user persona template* was further refined with more specific descriptions for interaction designers. This refinement was added to DHBC-Toolkit (Appendix 1–Section II). Three practitioner-experts (P1 – P3) further evaluated the proposed refined version. P1 has a background in designing DBCIs and was knowledgeable about behaviour change theories and had experience in designing DBCIs. P2 has experience designing user personas and a basic understanding of behaviour change theories. P3 has extensive experience in using personas in various industrial projects that were not directly

related to behaviour change. All practitioner-experts endorsed adding theoretical components to the regular persona template as useful for designing personas for behavioural change. Experts have proposed several suggestions for future iterations of the work.

- **User segments based on the transtheoretical model of change:** Although experts find this a helpful approach, they mentioned adding more information to explain why it is important to include them in the user persona (P1 and P2). P2 mentioned that the idea of pre-defined user segments is useful, but more description is needed for designers on how to understand the stage of change in complex behaviour change situations, such as when a user is in between two stages. I consider this a valuable insight, and in some cases, it might be possible that the user may have started seeking information and considering options (a sign of preparation), but still experience doubt or lack a full commitment to change (a sign of contemplation). This **“in-between” state** can be challenging for designers to segment users cleanly into just one stage. In future versions of the template, this could be addressed by adding more flexible options, such as “e.g., “contemplation-preparation” in the template to address such cases.
- **Behaviour change-related goals:** All experts considered it a valuable approach. P3 highlighted that it is important to mention where they come from. P2 mentioned that it is good to differentiate between broader goals and select and specify one target behaviour. P1 mentioned that it is good to combine the target behaviour and specification of the target behaviour to make it simpler and less complex for designers.
- **COM-B-based challenges and barriers.** All experts agreed that adding COM-B challenges and barriers is important for designing DBCIs. P3 mentioned renaming the section “COM-B-based Challenges & Barriers Related to Behaviour Change” as only “challenges and barriers” to make it less complex and understandable. However, from the my perspective, explicitly referencing COM-B in the section serves an important purpose. It provides clear guidance to designers by signalling that the challenges and barriers should be derived from user research conducted using the COM-B-based user research topic guide, thereby ensuring that the section remains theory-informed. P2 mentioned that a designer needs more boundary roadmaps to link findings with the overall design process.
- Other feedback includes recommendations for adding additional links to the related resources, mentioning the reason for the selection of theories, describing COM-B components more straightforwardly and less academically, presenting the template first and explaining the section in front of the template (rather than before or after the template), and lastly, improving the overall visual appeal of the toolkit.

The refined version of the final proposed *theory-enriched user persona guide* is presented in Appendix 1–Section II.

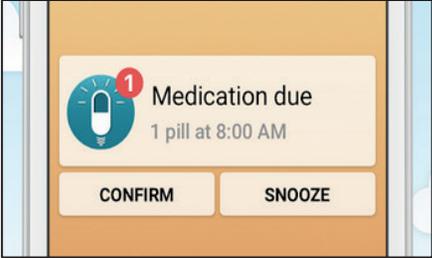
After understanding user needs and insights related to behaviour change and capturing them in a user persona, the next step is to select appropriate intervention functions and behaviour change techniques (BCTs). Michie, Atkins, et al. (2014) explain the process of selecting intervention functions and BCTs in detail. Given the challenges of operationalising BCTs in DBCIs, including a lack of practical guidance, fragmented and ad-hoc selection, and frequent mismatches between intended and actual BCT content (Conroy et al., 2014; Cowan et al., 2013; Dunn et al., 2018; Farhat-ul-Ain et al., 2022; Fulton et al., 2018; Lyons et al., 2014; Morrissey et al., 2016; Simeon et al., 2020; Thomson et al., 2016), I investigated the design pattern approach to aid interaction designers in operationalising BCTs. The background details about the design pattern approach are provided in the method section (6.2.3). This research was conducted in two steps and presented in papers (*Paper IV* and *Paper V*).

6.3. DESIGN PATTERNS FOR BEHAVIOUR CHANGE TECHNIQUES

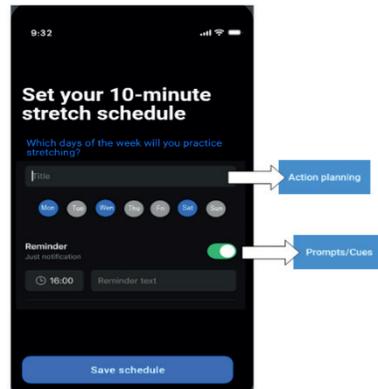
First, a literature review (*Paper IV*) was conducted to understand how various BCTs are operationalised in the DBCIs for health. The authors coded (*Paper IV*) techniques used in DBCIs using the behaviour change technique taxonomy (Michie et al., 2013). The result highlighted that some techniques are most frequently used in DBCIs, which include “prompts and cues”, “social support (unspecified)”, “goal setting (behaviour)”, “self-monitoring of behaviour”, “Instructions on how to perform a behaviour”, and “feedback on behaviour”. In the second phase of the research, the authors composed six individual patterns for six commonly used BCTs.

Table 12 presents an example of one design pattern for the “prompts and cues” technique. All design patterns are presented in DHBC toolkit (Appendix 1–Section III).

Table 12. Design Pattern for Prompts and Cues Technique (Paper V)

<p>Pattern Name: Reminder (alternative names: Prompt, Trigger, Cue, Call to action, Request)</p>	
<p>Code/BCT name (Group) in Taxonomy: 7.1 Prompts/Cues (Associations)</p>	
<p>Examples: AppleWatch reminder, activity app, myTherapyApp, StretchClock</p>	
 <p>A notification card with an orange background. It features a pill icon with a red '1' in a circle, followed by the text 'Medication due' and '1 pill at 8:00 AM'. At the bottom, there are two buttons: 'CONFIRM' and 'SNOOZE'.</p>	 <p>An Apple Watch notification showing the time '10:09' and the word 'STAND' in a blue bar. Below, it says 'Time to stand! Stand up and move a little for one minute.' with a green upward arrow icon.</p>
 <p>A screenshot of the 'My Motivators' app. It asks 'What are some of the strategies that are helpful to you to regularly be active?'. Two strategies are listed with star ratings: 'Have my music playlist and headphones ready to go.' (5 stars) and 'Pack a snack so I am not hungry and tempted to skip working out.' (4 stars).</p>	 <p>A notification from the 'StretchClock' app. It says 'Time to Stretch.' and includes a green heart icon with a stopwatch. The background shows a park scene. At the bottom, there's a system tray with weather 'Rain to stop', time '19:11', and date '28.03.2022'.</p>
<p>What (Problem): Users may have trouble remembering to perform or focus on some tasks during a certain period. Users want to be reminded, informed, or motivated about the tasks or activities to form a new habit or routine or not to perform undesired ones.</p>	
<p>Use when: Introduce to users a prompt or cue that can be used as a reminder to act or react in the direct context. This is useful when the user needs to be reminded or motivated to take some action in a specific context (e.g., take medication, remember a doctor’s appointment, take a standing pause to reduce sitting time, etc.) or rethink a planned or ongoing activity (e.g., take stairs instead of elevator, reduce speed, drink water instead of soda).</p>	
<p>How: Use notifications or prompts to encourage specific behaviour, such as taking medication at scheduled times. These reminders can be personalised and triggered based on user-defined settings or environmental cues. Reminders could be event-based or time-based. ‘Reminder’ could be user-generated, system-generated or generated by another person involved (e.g., a healthcare specialist). When designing, it is important to consider that these triggers may lead to alert fatigue, habituation, or user disregard of triggers (Muench & Baumel, 2017).</p>	
<p>Why: If ‘Reminder’ matches the time and the context – then the user is more likely to be motivated and able to take a needed action or complete a task.</p>	
<p>Design Principle and Theory: Behaviour change technique ‘Prompts/Cues’ as an intervention component is linked with Theoretical Domain Framework constructs ‘Memory, attention and decision processes’ and ‘Environmental context and resources’, therefore influences memory, attention, attention control, decision making, cognitive overload/tiredness (Atkins et al., 2017). Technique supports a person’s ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives.</p>	

BCTs combinations: When a stimulus is linked to a specific action in an if-then plan including one or more of frequency, duration or intensity “Action planning” can be applied.



In other collections: Trigger – Fogg’s Behaviour change model (<https://behaviormodel.org/prompts/>), Reminder Pattern – ‘Software patterns for persuasive computer-human dialogue’ (Little et al., 2017), Reminding – Designing Social Interfaces: Principles, Patterns, and Practices for Improving the User Experience (Crumlish, 2009)

Next, evaluations were conducted with four interaction design practitioner-experts. The results indicated that although design patterns were understandable and helpful, they were primarily more suitable for academic researchers. The patterns need to be simpler and more precise for designers. The practitioner-experts’ evaluation suggested simplifying the language for industry professionals and adding additional elements that can highlight what not to do and words of caution when operationalising BCTs. This indicates further refinement of design patterns is required.

6.4. DIGITAL BEHAVIOUR CHANGE (DHBC) TOOLKIT FOR INTERACTION DESIGNERS

The DHBC Toolkit, based on the tools presented in Sections 7.1, 7.2, and 7.3, was compiled as a practical handbook for interaction designers. It provides structured guidance, theory-informed templates, and reusable design patterns to support the design of DBCIs. The DHBC toolkit has three sections (Appendix 1).

- Section I contains a *theory-enriched user research topic guide* with detailed guidelines on using and adapting the topic guide.
- Section II contains a *theory-enriched user persona guide* with detailed guidelines for each section and an example of a user persona for DBCIs.
- Section III contains a set of *design patterns for BCTs*, providing practical, reusable strategies for operationalising BCTs in DBCIs.

7. DISCUSSION AND RECOMMENDATIONS

This chapter provides a comprehensive analysis of the findings presented in the previous sections and reflects on their significance. It also outlines the current study's limitations and potential directions for future research, aiming to refine and extend this work's contributions.

The objective of the current study was to “*shape and enrich existing tools in a way that can facilitate the design of DBCIs for health by integrating behaviour change theories into interaction design tools*”. To achieve this, the current research proposed the DHBC toolkit, which included a *theory-enriched user research topic guide* for interviews and focus groups, a *theory-enriched user persona guide*, and *design patterns* for BCTs. The tools developed as part of this research can be directly applied to the design of DBCIs.

For interaction designers, the current study highlights the importance of incorporating behaviour change theories early in the design process for designing DBCIs for health. The case study results highlighted a more structured and holistic understanding of the needs of children diagnosed with Type I Diabetes, which can guide the design of DBCIs for health. Interaction designers can begin by conducting focus groups or interviews to gather relevant and comprehensive data on behaviour change (determinants of behaviour, stage of change, etc.). Using the COM-B model, designers can focus on a broad range of critical determinants of behaviour. Readily available topic guides and toolkits will save designers time and resources in extensively reviewing existing behaviour change theories and making results actionable for the design process. As behaviour change is a long-term process, the proposed topic guide will help in iterative data collection and refining results based on the study results. The proposed *theory-enriched user research topic guide* was based on the COM-B model. The designers can use a similar approach if they aim to use any other theory, for example, the theory of planned behaviour or the health belief model. Results from the case evaluation show how the topic guide highlighted that designers can achieve a more holistic understanding of behaviour change-related needs. Designers can adapt topic guides according to their needs and problems at hand.

The *theory-enriched user research topic guide* was evaluated through a case study focused on understanding the needs of children with Type I Diabetes. This approach provided valuable insights into how the guide functions in a real design context, particularly in helping designers identify behavioural determinants during the user research phase. Future work could extend the evaluation of the *theory-enriched user research topic guide* by incorporating both expert feedback and practitioner feedback. Expert feedback would help to assess the guide's theoretical coherence, particularly its alignment with the COM-B model, and the clarity of its question structure. Practitioner feedback could help to understand its adaptability, ease of use, and perceived value in diverse and time-constrained design environments.

The *theory-enriched topic guide* may present challenges when applied in practical design settings. Since COM-B encompasses three broad and interrelated domains, it requires a solid conceptual understanding to be applied effectively. Using the COM-B model in interviews or focus groups can generate large volumes of qualitative data, making analysis and interpretation time-consuming and cognitively demanding for designers. Without adequate behavioural expertise, there is a risk of either overgeneralising or misclassifying information. For example, confusing psychological capability with motivation or overlooking environmental opportunities. For designers unfamiliar with behavioural theory, this learning curve and analytical complexity may limit adoption. However, when supplemented with clear examples, structured prompts, and practical guidance, the topic guide can support the generation of richer, theory-informed user insights. Therefore, its effective use depends on a strong understanding of COM-B domains and appropriate training in conducting and analysing theory-informed user research.

The *theory-enriched user persona guide* was developed to shape a regular user persona template by adding different sections to capture specific information related to behaviour change. Different sections in the regular user persona template were modified using the Transtheoretical Model of Change and the COM-B model. The *theory-enriched user persona guide* can enable designers to develop interventions that align with the target audience's behavioural goals, stage of change, and challenges and barriers related to behavioural change. It will allow the design of more relevant solutions that are more likely to facilitate behaviour change. Understanding the stages of change and reflecting them as segments will allow us to select appropriate BCTs to help them move to the next stage. When designing DBCIs, it is essential to view the theory-enriched user research topic guide template and user persona templates as living documents, meaning that the content within them should be continuously updated and refined throughout the design process. These need to be updated as new information is gathered, and they must always reflect the latest insights. Furthermore, expert and practitioner evaluations suggested better template design, such as adding a template before theoretical information, keeping information simpler for designers, needing better guidance on selecting and specifying target behaviour, and clarifying how COM-B-based challenges could be used in the design process. Overall, the *theory-enriched persona guide* extends traditional persona templates by incorporating segmentation based on stages of change, behavioural goals and determinants of behaviour. This integration allows designers to interpret user behaviour specifically in the context of behaviour change needs, linking what users aim to achieve with their readiness and ability to change. However, practitioners accustomed to regular persona templates may find the inclusion of behavioural constructs and stage-based reasoning conceptually demanding and time-intensive to apply in practice.

Design patterns are reusable solutions to common design problems. Providing design patterns grounded in behavioural science will enable designers to systematically apply proven methods of operationalising BCTs within the context of DBCIs. The

practitioner-based evaluation indicated a need for further refinement of the design pattern. The practitioners provided valuable suggestions for future iterations of the *design patterns for BCTs*. They mentioned that design patterns need to be simplified, and overall, the language should be more practice-oriented than academic. A practitioner with experience in designing DBCIs noted that it is essential to add a section on what not to do when operationalising BCTs in DBCIs. I recognise this as an important suggestion since BCTs must be cautious when operationalising DBCIs. For example, the satiation concept highlights that the effectiveness of rewards can decrease over time if they become too predictable or routine. This suggests that receiving rewards every time after achieving goals may diminish the value of those rewards over time. To prevent such outcomes, designers can use BCTs such as scheduled rewards. Including such guidelines in design patterns would enhance the design of DBCIs. One role of design patterns is to support multidisciplinary communication, such as with developers. One practitioner disagreed, stating that design patterns might not be helpful for developers. I partially agreed that design patterns are general solutions to common design issues rather than providing technical solutions; however, proposed design patterns can still be utilised as they offer a common language for discussion among teams and help developers understand the primary intent of BCTs, ensuring that interaction designers and system designers remain aligned.

Design patterns for BCTs can inform ideation, prototyping, and refinement. However, their effective use still requires designers to engage in careful reading and interpretation of detailed pattern descriptions. Some practitioners may find the patterns lengthy or written in overly academic language, making them challenging to apply. The illustrative examples included in some patterns, while helpful in demonstrating application, may inadvertently constrain design exploration by leading designers to replicate existing examples rather than adapting them in their related contexts.

The *theory-enriched persona guide* was reviewed by both *interaction design* experts and practising designers. These evaluations have several limitations. The small number of practitioner-experts, along with the absence of real project-based testing, limits understanding of the practical challenges designers may face when using the guides. Moreover, the evaluations focused on individual artefacts rather than assessing the DHBC toolkit as an integrated whole, making it difficult to determine how its components work together in practice. Future studies should therefore evaluate the complete toolkit in real design contexts.

The DHBC-toolkit is intended for both professional interaction designers and design students who engage with designing digital health behaviour change-related projects. In professional contexts, designers often work independently or within small teams, with limited knowledge of behavioural science frameworks and structured approaches to integrating theory into design. Similarly, design students or early-career practitioners frequently lack guidelines to apply health behaviour

theories systematically during design processes. Interaction designers would be motivated to adopt the DHBC-toolkit because it addresses a practical gap in their practice, i.e., the lack of accessible, ready-to-use resources for combining theory with *interaction design* practice. It supports interaction designers in identifying behavioural determinants, translating them into actionable user insights, and linking these to relevant BCTs. In doing so, the toolkit advances a more coherent and theory-informed design practice, strengthening the connection between behavioural science and *interaction design*.

The DHBC-toolkit is not designed to replace collaboration with health or behavioural experts but to enhance multidisciplinary communication and ensure that behavioural goals remain central throughout the design process. By providing structured, theory-informed tools, it enables designers to engage more effectively with practitioners from other disciplines and to make behavioural considerations explicit in design discussions. At the same time, the toolkit can also serve as a standalone resource for teams without direct access to behaviour change experts, offering practical guidance for translating behavioural theory into design practice. In both cases, it acts as a supportive resource that fosters mutual understanding across disciplines and helps maintain a consistent focus on behavioural outcomes within digital *intervention design*.

The DHBC-toolkit is designed to be flexible so that it can be updated or revised as new knowledge in behaviour change becomes available. For example, the topic guide can be expanded with new interview questions or behavioural domains as research identifies additional determinants of behaviour. The persona template can be refined to include either new psychological constructs or behavioural stages. Additional design patterns can be developed to represent more complex BCTs. Moreover, the toolkit encourages reflective use, allowing designers and researchers to document insights and modify examples if needed. This iterative approach would help ensure that the toolkit remains both theoretically and practically relevant in a rapidly evolving research landscape.

This research has certain limitations, primarily due to time and resource constraints, which may have restricted the extent to which the proposed tools could be further refined. The developed tools and templates were evaluated qualitatively using expert feedback and case study methods. While expert evaluations provided valuable insights, the limited number of experts involved, particularly experts working in the field of DBCIs for health, might have constrained the breadth of feedback and the identification of potential improvements. This limits the understanding of how these tools perform in real-world settings and the problems designers might have while using these tools in actual design settings. Future research needs to evaluate these templates in actual design settings to understand issues that designers might have while using these tools and refine them. This research suggests the potential for a new model that blends the COM-B framework with User-Centred Design and Goal-Directed Design. Such a model could serve as a foundation for designing DBCIs that are theoretically sound and adhere to the design guidelines.

CONCLUSION

The study objectives were to shape and enrich existing tools in a way that can facilitate the design of DBCIs for health by integrating behaviour change theories into *interaction design* methods. As a result, a DHBC toolkit was proposed that includes the *theory-enriched user research topic guide*, *theory-enriched user persona guide* and *design patterns for BCTs*. These tools are intended to facilitate a deeper understanding of user behaviour and to bridge the practical gap between intervention and *interaction design*.

This research demonstrates how theoretical constructs can be operationalised in practical design contexts by systematically applying the COM-B model and other behaviour change frameworks to user research and persona development. The thesis adds to the field of *interaction design* by providing a set of Design Patterns specifically for BCTs. These design patterns could be used as a manual or toolkit for designers when operationalising BCTs in DBCIs. This is particularly important in the context of DBCIs where precise and thoughtful application of BCTs often determines intervention success. This study's practical contribution includes developing theory-based tools that provide a structured approach for integrating insights from behaviour change theories into the design process. This research provides a valuable practical resource for designing goal-oriented DBCIs grounded in solid theoretical foundations for behaviour change. These tools move beyond conventional methods by focusing on determinants of behaviour, stage of behaviour change, and specific needs and goals. By equipping designers with these templates, the thesis provides a practical means for understanding and addressing the unique challenges associated with behaviour change, leading to better design of DBCIs.

This study's theoretical implications are significant, particularly in advancing the integration of behaviour change theories within the field of *interaction design*. This contribution is particularly relevant in the context of digital health, where the efficacy of interventions is often tied to the accuracy with which they address the user behaviour patterns and needs, leading to better outcomes in various domains. This approach bridges the gap between theory and practice. It contributes to the body of knowledge in both fields by providing a clear pathway for incorporating psychological and behavioural insights into the design process.

The current study aims for a substantial societal impact. By equipping interaction designers with a deeper understanding of behaviour change-related needs, this study empowers them to design more user-centred digital products that better support behaviour change. As a result, individuals can experience improved health, enhanced well-being, and a higher quality of life. At the same time, the broader social systems benefit from reduced strain on healthcare and support services. Thus, this research contributes not only to academic knowledge and design practice but also to fostering meaningful, long-term societal benefits.

REFERENCES

- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A pattern language: Towns, buildings, construction*. Oxford University Press.
- Alsalmán, D., Ali, Z. M. B., Alnosaier, Z. F., Alotaibi, N. A., & Alanzi, T. M. (2020). Gamification for diabetes type 1 management: A review of the features of free apps in Google Play and App Stores. *Journal of Multidisciplinary Healthcare*, 13, 425–432. <https://doi.org/10.2147/JMDH.S249664>
- Asbjørnsen, R. A., Hjelmæsæth, J., Smedsrød, M. L., Wentzel, J., Clark, M. M., Kelders, S. M., van Gemert-Pijnen, J. E. W. C., & Solberg Nes, L. (2024). Implementation of a digital behavior change intervention (eCHANGE) for weight loss maintenance support: A service design and technology transfer approach. *Frontiers in Digital Health*, 6, 1394599. <https://doi.org/10.3389/fdgth.2024.1394599>
- Atkins, L., Francis, J., Islam, R., O'Connor, D., Patey, A., Ivers, N., Foy, R., Duncan, E. M., Colquhoun, H., Grimshaw, J. M., Lawton, R., & Michie, S. (2017). A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. *Implementation Science*, 12(1), 1–18. <https://doi.org/10.1186/S13012-017-0605-9/TABLES/10>
- Bartholomew, L. K., & Mullen, P. D. (2011). Five roles for using theory and evidence in the design and testing of behavior change interventions. *Journal of Public Health Dentistry*, 71(SUPPL. 1), S20–S33. <https://doi.org/10.1111/J.1752-7325.2011.00223.X>
- Bhattacharyya, O., Mossman, K., Gustafsson, L., & Schneider, E. C. (2019). Using human-centred design to build a digital health advisor for patients with complex needs: Persona and prototype development. *Journal of Medical Internet Research*, 21(5), e10318. <https://doi.org/10.2196/10318>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706QP063OA>
- Cane, J., O'Connor, D., & Michie, S. (2012). Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation Science*, 7(1). <https://doi.org/10.1186/1748-5908-7-37>
- Castensøe-Seidenfaden, P., Husted, G. R., Jensen, A. K., Hommel, E., Olsen, B., Pedersen-Bjergaard, U., Kensing, F., & Teilmann, G. (2018). Testing a smartphone app (Young with diabetes) to improve self-management of diabetes over 12 months: Randomized controlled trial. *JMIR MHealth and UHealth*, 6(6). <https://doi.org/10.2196/mhealth.9487>
- Chiu, M. C., Chang, S. P., Chang, Y. C., Chu, H. H., Chen, C. C. H., Hsiao, F. H., & Ko, J. C. (2009). Playful bottle: A mobile social persuasion system to motivate healthy water intake. *ACM International Conference Proceeding Series*, 185–194. <https://doi.org/10.1145/1620545.1620574>

- Colusso, L., Do, T., & Hsieh, G. (2018). Behavior change design sprints. *DIS 2018 - Proceedings of the 2018 Designing Interactive Systems Conference*, 791–804. <https://doi.org/10.1145/3196709.3196739>
- Conroy, D. E., Yang, C.-H., & Maher, J. P. (2014). Behavior change techniques in top-ranked mobile apps for physical activity. *American Journal of Preventive Medicine*, 46(6), 649–652. <https://doi.org/10.1016/j.amepre.2014.01.010>
- Cooper, A., Reimann, R., Cronin, D., Noessel, C., Csizmadi, J., & Lemoine, D. (2014). *About face: The essentials of interaction design* (4th ed.). John Wiley & Sons, Inc.
- Cougnon, L.-A., & Anciaux, A. (2024). VEPR: A mixed-method approach for including sociological profiles in audience segmentation for communication campaigns. *Annals of Social Sciences & Management Studies*, 11(1), 001–0013. <https://doi.org/10.19080/ASM.2024.11.555801>
- Cowan, L. T., van Wagenen, S. A., Brown, B. A., Hedin, R. J., Seino-Stephan, Y., Hall, P. C., & West, J. H. (2013). Apps of steel: are exercise apps providing consumers with realistic expectations?: A content analysis of exercise apps for presence of behavior change theory. *Health Education & Behavior: The Official Publication of the Society for Public Health Education*, 40(2), 133–139. <https://doi.org/10.1177/1090198112452126>
- Dahiya, A., & Kumar, yoti. (2018, April). *How Empathizing With Persona Helps In Design Thinking: An Experimental Study With Novice Designers*.
- Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: A scoping review. *Health Psychology Review*, 9(3), 323. <https://doi.org/10.1080/17437199.2014.941722>
- Goodwin, K. (2009). *Designing for the digital age: How to create human-centered products and services*. Wiley Publishing, Inc.
- Dunn, E. E., Gainforth, H. L., & Robertson-Wilson, J. E. (2018). Behavior change techniques in mobile applications for sedentary behavior. *Digital Health*, 4, 205520761878579. <https://doi.org/10.1177/2055207618785798>
- Emmanuel, G. S., & Polito, F. (2022). How Related Are Designers to the Personas They Create? *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13323 LNCS, 3–13. https://doi.org/10.1007/978-3-031-05906-3_1
- Evans, W. D., Abroms, L. C., Broniatowski, D., Napolitano, M. A., Arnold, J., Ichimiya, M., & Agha, S. (2022). Digital media for behavior change: Review of an emerging field of study. *International Journal of Environmental Research and Public Health*, 19(15). <https://doi.org/10.3390/IJERPH19159129>
- Eyles, H., McLean, R., Neal, B., Doughty, R. N., Jiang, Y., & Ni Mhurchu, C. (2014). Using mobile technology to support lower-salt food choices for people with cardiovascular disease: Protocol for the SaltSwitch randomised controlled trial. *BMC Public Health*, 14, 950. <https://doi.org/10.1186/1471-2458-14-950>
- Ellis, J. T., & Levy, Y. (2010). A guide for novice researchers: Design and development research methods. *Proceedings of the 2010 InSITE Conference*, 107–118. <https://doi.org/10.28945/1237>

- Farhat-ul-Ain, Popovič, O., & Tomberg, V. (2022). Mapping behavior change wheel techniques to digital behavior change interventions: Review. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13304 LNCS, 277–295. https://doi.org/10.1007/978-3-031-05412-9_20
- Ferreira, B., Santos, G., & Conte, T. (2017). Identifying possible requirements using personas: A qualitative study. *ICEIS 2017 - Proceedings of the 19th International Conference on Enterprise Information Systems*, 2, 64–75. <https://doi.org/10.5220/0006311600640075>
- Forthofer, M. S., & Bryant, C. A. (2000). Using audience-segmentation techniques to tailor health behavior change strategies. *American Journal of Health Behavior*, 24(1), 36–43. <https://doi.org/10.5993/AJHB.24.1.6>
- Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., Patel, V., & Haines, A. (2013). The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: A systematic review. *PLOS Medicine*, 10(1), e1001362. <https://doi.org/10.1371/journal.pmed.1001362>
- French, S. D., Green, S. E., O'Connor, D. A., McKenzie, J. E., Francis, J. J., Michie, S., Buchbinder, R., Schattner, P., Spike, N., & Grimshaw, J. M. (2012). Developing theory-informed behaviour change interventions to implement evidence into practice: a systematic approach using the Theoretical Domains Framework. *Implementation Science*, 7(1), 1–8. <https://doi.org/10.1186/1748-5908-7-38/TABLES/3>
- Fulton, E. A., Kwah, K. L., Wild, S., & Brown, K. E. (2018). Lost in translation: Transforming behaviour change techniques into engaging digital content and design for the StopApp. *Healthcare*, 6(3). <https://doi.org/10.3390/healthcare6030075>
- Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC medical research methodology*, 13, 117. <https://doi.org/10.1186/1471-2288-13-117>
- Grand View Research. (2024). *Europe mHealth market size & outlook, 2023–2030*. <https://www.grandviewresearch.com/horizon/outlook/mhealth-market/europe>
- Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, 3, 275–285. <https://doi.org/10.1016/J.SUSOC.2022.05.004>
- Halonen, E. (2024). Is the Behaviour Change Wheel still valid? *Square Peg Insight*. <https://www.squarepeginsight.com/post/is-the-behaviour-change-wheel-bcw-still-valid>
- Health, T. L. D. (2019). Wearable technology and lifestyle management: the fight against obesity and diabetes. *The Lancet. Digital Health*, 1(6), e243. [https://doi.org/10.1016/S2589-7500\(19\)30135-9](https://doi.org/10.1016/S2589-7500(19)30135-9)
- Hoepfner, B. B., Hoepfner, S. S., Kelly, L., Schick, M., & Kelly, J. F. (2017). Smiling instead of smoking: Development of a positive psychology smoking cessation smartphone app for non-daily smokers. *International Journal of Behavioral Medicine*, 24(5), 683–693. <https://doi.org/10.1007/s12529-017-9640-9>
- Hutchesson, M. J., Morgan, P. J., Callister, R., Pranata, I., Skinner, G., & Collins, C. E. (2016). Be Positive Be Health: Development and implementation of a targeted e-health weight loss

- program for young women. *Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association*, 22(6), 519–528. <https://doi.org/10.1089/tmj.2015.0085>
- Jones, M., & Marsden, G. (2006). *Mobile interaction design*. John Wiley & Sons.
- Kitunen, A., Carins, J., Isbanner, S., & Rundle-Thiele, S. (2025). Using segmentation to co-design a healthy eating program. *Health Marketing Quarterly*. <https://doi.org/10.1080/07359683.2025.2478350>
- Klonoff, D. C. (2019). Behavioral theory: The missing ingredient for digital health tools to change behavior and increase adherence. *Journal of Diabetes Science and Technology*, 13(2), 276–281. <https://doi.org/10.1177/1932296818820303>
- Konstanti, C., Karapanos, E., & Markopoulos, P. (2022). The behavior change design cards: A design support tool for theoretically-grounded design of behavior change technologies. *International Journal of Human-Computer Interaction*, 38(13), 1238–1254. <https://doi.org/10.1080/10447318.2021.1990519>
- Kowatsch, T., Otto, L., Harperink, S., Cotti, A., & Schlieter, H. (2019). A design and evaluation framework for digital health interventions. *IT - Information Technology*, 61(5–6), 253–263. <https://doi.org/10.1515/itit-2019-0019>
- Krueger, R. A., & Casey, M. A. (2014). *Focus groups: A practical guide for applied research* (5th ed.). SAGE Publications.
- Laranjo, L., Ding, Di., Heleno, B., Kocaballi, B., Quiroz, J. C., Tong, H. L., Chahwan, B., Neves, A. L., Gabarron, E., Dao, K. P., Rodrigues, D., Neves, G. C., Antunes, M. L., Coiera, E., & Bates, D. W. (2021). Do smartphone applications and activity trackers increase physical activity in adults? Systematic review, meta-analysis and metaregression. *British Journal of Sports Medicine*, 55(8), 422–432. <https://doi.org/10.1136/BJSPORTS-2020-102892>
- Lárusdóttir, M., Wang, R., & Cajander, Å. (2022). Contextual personas - A method for capturing the digital work environment of users. In C. Ardito, R. Lanzilotti, A. Malizia, M. Larusdottir, L. D. Spano, J. Campos, M. Hertzum, T. Mentler, J. Abdelnour Nocera, L. Piccolo, S. Sauer, & G. van der Veer (Eds.), *Sense, feel, design - INTERACT 2021 IFIP TC 13 workshops, revised selected papers* (pp. 98–112). Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 13198 LNCS. Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-030-98388-8_10
- Lisowska, A., Wilk, S., & Peleg, M. (2023). SATO (IDEAS expANded wiTh BCIO): Workflow for designers of patient-centered mobile health behaviour change intervention applications. *Journal of Biomedical Informatics*, 138, 104276. <https://doi.org/10.1016/j.jbi.2022.104276>
- Lyons, E. J., Lewis, Z. H., Mayrsohn, B. G., & Rowland, J. L. (2014). Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis. *Journal of Medical Internet Research*, 16(8), e192. <https://doi.org/10.2196/JMIR.3469>
- Mamykina, L., Miller, A. D., Medynskiy, Y., Grevet, C., Davidson, P. R., Terry, M. A., & Mynatt, E. D. (2011). Examining the impact of collaborative tagging on sensemaking in nutrition management. *Conference on Human Factors in Computing Systems - Proceedings*, 657–666. <https://doi.org/10.1145/1978942.1979037>

- Massanari, A. L. (2010). Designing for imaginary friends: information architecture, personas and the politics of user-centered design. *New Media & Society*, 12(3), 401–416. <https://doi.org/10.1177/1461444809346722>
- Miaskiewicz, T., Grant, S. J., & Kozar, K. A. (2009). A preliminary examination of using personas to enhance user-centered design. *AMCIS 2009 Proceedings*, 697. <https://aisel.aisnet.org/amcis2009/697>
- Michie, S., Atkins, L., & West, R. (2014). *The behaviour change wheel: A guide to designing interventions*. Silverback.
- Michie, S., & Johnston, M. (2012). Theories and techniques of behaviour change: Developing a cumulative science of behaviour change. *Health Psychology Review*, 6(1), 1–6. <https://doi.org/10.1080/17437199.2012.654964>
- Michie, S., & Prestwich, A. (2010). Are interventions theory-based? Development of a theory coding scheme. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, 29(1), 1–8. <https://doi.org/10.1037/A0016939>
- 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. <https://doi.org/10.1007/S12160-013-9486-6>
- Michie, S., Stralen, M. M. van, & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, 6(1), 1–12. <https://doi.org/10.1186/1748-5908-6-42>
- Michie, S., West, R., Campbell, R., Brown, J., & Gainforth, H. (2014). *ABC of behaviour change theories*. Silverback Publishing.
- Mohr, D. C., Schueller, S. M., Montague, E., Burns, M. N., & Rashidi, P. (2014). The behavioral intervention technology model: an integrated conceptual and technological framework for eHealth and mHealth interventions. *Journal of Medical Internet Research*, 16(6). <https://doi.org/10.2196/JMIR.3077>
- Moller, A. C., Merchant, G., Conroy, D. E., West, R., Hekler, E., Kugler, K. C., & Michie, S. (2017). Applying and advancing behavior change theories and techniques in the context of a digital health revolution: proposals for more effectively realizing untapped potential. *Journal of Behavioral Medicine*, 40(1), 85–98. <https://doi.org/10.1007/S10865-016-9818-7>
- Monteiro-Guerra, F., Rivera-Romero, O., Mylonopoulou, V., Signorelli, G. R., Zambrana, F., & Fernandez-Luque, L. (2017). The design of a mobile app for promotion of physical activity and self-management in prostate cancer survivors: Personas, feature ideation, and low-fidelity prototyping. *Proceedings of the 2017 IEEE 30th International Symposium on Computer-Based Medical Systems (CBMS)*, 761–766. <https://doi.org/10.1109/CBMS.2017.75>
- Morrison, L. G. (2015). Theory-based strategies for enhancing the impact and usage of digital health behaviour change interventions: A review. *Digital Health*, 1, 2055207615595335. <https://doi.org/10.1177/2055207615595335>

- Morrissey, E. C., Corbett, T. K., Walsh, J. C., & Molloy, G. J. (2016). Behavior change techniques in apps for medication adherence: A content analysis. *American Journal of Preventive Medicine*, *50*(5), e143–e146. <https://doi.org/10.1016/J.AMEPRE.2015.09.034>
- Muench, F., & Baumel, A. (2017). More than a text message: Dismantling digital triggers to curate behavior change in patient-centered health interventions. *Journal of Medical Internet Research*, *19*(5), e147. <https://doi.org/10.2196/jmir.7463>
- Mummah, S. A., Robinson, T. N., King, A. C., Gardner, C. D., & Sutton, S. (2016). IDEAS (integrate, design, assess, and share): A framework and toolkit of strategies for the development of more effective digital interventions to change health behavior. *Journal of Medical Internet Research*, *18*(12). <https://doi.org/10.2196/jmir.5927>
- Murray, E., Burns, J., See, T. S., Lai, R., & Nazareth, I. (2005). Interactive health communication applications for people with chronic disease. *The Cochrane Database of Systematic Reviews*, *2005*(4), CD004274. <https://doi.org/10.1002/14651858.CD004274.pub4>
- Oinas-Kukkonen, H. (2010). Behavior change support systems: A research model and agenda. In T. Ploug, P. Hasle, & H. Oinas-Kukkonen (Eds.), *Persuasive technology: PERSUASIVE 2010* (Vol. 6137, pp. 37–50). Springer. https://doi.org/10.1007/978-3-642-13226-1_3
- Piscicelli, L. (2023). The sustainability impact of a digital circular economy. *Current Opinion in Environmental Sustainability*, *61*, 101251. <https://doi.org/10.1016/J.COSUST.2022.101251>
- Pradal-Cano, L., Lozano-Ruiz, C., Pereyra-Rodríguez, J. J., Saigí-Rubió, F., Bach-Faig, A., Esquius, L., Xavier Medina, F., & Aguilar-Martínez, A. (2020). Using mobile applications to increase physical activity: A systematic review. *International Journal of Environmental Research and Public Health*, *17*(21), 1–16. <https://doi.org/10.3390/IJERPH17218238>
- Preece, J., Sharp, H., & Rogers, Y. (2015). *Interaction design: Beyond human-computer interaction* (4th ed.). Wiley.
- Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. *American Journal of Health Promotion*, *12*(1), 38–48. <https://doi.org/10.4278/0890-1171-12.1.38>
- Pruitt, J., & Grudin, J. (2003). Personas: Practice and theory. *Proceedings of the 2003 Conference on Designing for User Experiences, DUX '03*. <https://doi.org/10.1145/997078.997089>
- Saffer, D. (2009). *Designing for interaction: Creating innovative applications and devices* (2nd ed.). New Riders.
- Salminen, J., Guan, K. W., Jung, S.-G., & Jansen, B. (2022). Use cases for design personas: A systematic review and new frontiers. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22)*, Article 543, 1–21. Association for Computing Machinery. <https://doi.org/10.1145/3491102.3517589>
- Sediva, H., Cartwright, T., Robertson, C., & Deb, S. K. (2022). Behavior change techniques in digital health interventions for midlife women: Systematic review. *JMIR MHealth and UHealth*, *10*(11), e37234. <https://doi.org/10.2196/37234>

- Seffah, A. (2010). The evolution of design patterns in HCI. *Proceedings of the 1st International Workshop on Pattern-Driven Engineering of Interactive Computing Systems*, 4–9. <https://doi.org/10.1145/1824749.1824751>
- Shadie, R., Reynolds, B. L., & Li, R. (2024). The use of digital technology for sustainable teaching and learning. *Sustainability*, 16(13), Article 5353. <https://doi.org/10.3390/su16135353>
- Sharp, H., Rogers, Y., & Preece, J. (2019). *Interaction design: Beyond human-computer interaction*. Wiley.
- Simeon, R., Dewidar, O., Trawin, J., Duench, S., Manson, H., Pardo, J. P., Petkovic, J., Roberts, J. H., Tugwell, P., Yoganathan, M., Presseau, J., & Welch, V. (2020). Behavior change techniques included in reports of social media interventions for promoting health behaviors in adults: Content analysis within a systematic review. *Journal of Medical Internet Research*, 22(6). <https://doi.org/10.2196/16002>
- Stewart, D. W., Shamdasani, P. N., & Rook, D. W. (2007). *Focus groups*. SAGE Publications, Ltd., <https://doi.org/10.4135/9781412991841>
- Skivington, K., Matthews, L., Simpson, S. A., Craig, P., Baird, J., Blazeby, J. M., Boyd, K. A., Craig, N., French, D. P., McIntosh, E., Petticrew, M., Rycroft-Malone, J., White, M., & Moore, L. (2021). A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ*, 374. <https://doi.org/10.1136/BMJ.N2061>
- Slater, M. D. (1996). Theory and method in health audience segmentation. *Journal of Health Communication*, 1(3), 267–283. <https://doi.org/10.1080/108107396128059>
- Smith, R. A. (2017). Audience segmentation techniques. *Oxford Research Encyclopedia of Communication*. <https://doi.org/10.1093/ACREFORE/9780190228613.013.321>
- Sohi, I., Shield, K. D., Rehm, J., & Monteiro, M. (2023). Digital interventions for reducing alcohol use in general populations: An updated systematic review and meta-analysis. *Alcohol: Clinical and Experimental Research*, 47(10), 1813–1832. <https://doi.org/10.1111/ACER.15175>
- Still, B., & Crane, K. (2017). Fundamentals of user-centered design. In *Fundamentals of User-Centered Design* (pp. 1–22). CRC Press. <https://doi.org/10.4324/9781315200927>
- Stolterman, E., & Wiberg, M. (2010). Human-computer interaction concept-driven interaction design research. *International Journal of Human-Computer Interaction*, 25(2), 95–118. <https://doi.org/10.1080/07370020903586696>
- Sucala, M., Ezeanochie, N. P., Cole-Lewis, H., & Turgiss, J. (2020). An iterative, interdisciplinary, collaborative framework for developing and evaluating digital behavior change interventions. *Translational Behavioral Medicine*, 10(6), 1538–1548. <https://doi.org/10.1093/TBM/IBZ109>
- Taj, F., Klein, M. C. A., & Van Halteren, A. (2019). Digital health behavior change technology: Bibliometric and scoping review of two decades of research. *JMIR MHealth and UHealth*, 7(12), e13311. <https://doi.org/10.2196/13311>

- Thomson, C., Nash, J., & Maeder, A. (2016). Persuasive design for behaviour change apps: Issues for designers. *ACM International Conference Proceeding Series*, 26-28-September-2016. <https://doi.org/10.1145/2987491.2987535>
- Tidwell, J., Brewer, C., & Valencia, A. (2010). *Designing interfaces: Patterns for effective interaction design* (2nd ed.). O'Reilly Media.
- Tieben, R. (2015). Activating play : a design research study on how to elicit playful interaction from teenagers. [Phd Thesis 1 (Research TU/e / Graduation TU/e), Industrial Design]. Technische Universiteit Eindhoven. <https://pure.tue.nl/ws/portalfiles/portal/3857195/798382.pdf>
- Truelove, S., Vanderloo, L. M., Tucker, P., Di Sebastiano, K. M., & Faulkner, G. (2020). The use of the behaviour change wheel in the development of ParticipACTION's physical activity app. *Preventive Medicine Reports*, 20, 101224. <https://doi.org/10.1016/J.PMEDR.2020.101224>
- Voorheis, P., Bhuiya, A. R., Kuluski, K., Pham, Q., & Petch, J. (2023). Making sense of theories, models, and frameworks in digital health behavior change design: Qualitative descriptive study. *Journal of Medical Internet Research*, 25(1), e45095. <https://doi.org/10.2196/45095>
- Wang, Y., Fadhil, A., Lange, J. P., & Reiterer, H. (2019). Integrating taxonomies into theory-based digital health interventions for behavior change: A holistic framework. *JMIR Research Protocols*, 8(1), e8055. <https://doi.org/10.2196/RESPROT.8055>
- Whittaker, R., McRobbie, H., Bullen, C., Rodgers, A., & Gu, Y. (2016). Mobile phone-based interventions for smoking cessation. *The Cochrane Database of Systematic Reviews*, 2016(4). <https://doi.org/10.1002/14651858.CD006611.PUB4>
- Wei, C., & Fang, X. (2010). The comparison of user-centered design and goal-directed design. *2010 IEEE 11th International Conference on Computer-Aided Industrial Design & Conceptual Design*, 1, 359–360. <https://doi.org/10.1109/CAIDCD.2010.5681336>
- Williams, A. (2009). User-centered design, activity-centered design, and goal-directed design: A review of three methods for designing web applications. *SIGDOC'09 - Proceedings of the 27th ACM International Conference on Design of Communication*, 1–8. <https://doi.org/10.1145/1621995.1621997>
- World Health Organisation. (2020). *Youth-Centred Digital Health Interventions: A framework for planning, developing, and implementing solutions with and for young people*. <https://www.unfpa.org/publications/youth-centred-digital-health-interventions-framework-planning-developing-and>
- Wurhofer, D., Obrist, M., Beck, E., & Tscheligi, M. (2010). A quality criteria framework for pattern validation. *International Journal on Advances in Software*, 3 (1 & 2), 252–264. https://personales.upv.es/thinkmind/dl/journals/soft/soft_v3_n12_2010/soft_v3_n12_2010_19.pdf
- Wurhofer, D., Obrist, M., Beck, E., & Tscheligi, M. (2009). Introducing a comprehensive quality criteria framework for validating patterns. *2009 Computation World: Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns*, 242–247. <https://doi.org/10.1109/computationworld.2009.86>

Xia, L., Baghaie, S., & Mohammad Sajadi, S. (2024). The digital economy: Challenges and opportunities in the new era of technology and electronic communications. *Ain Shams Engineering Journal*, 15(2), 102411. <https://doi.org/10.1016/J.ASEJ.2023.102411>

Young, S. D. (2020). The Adaptive Behavioral Components (ABC) model for planning longitudinal behavioral technology-based health interventions: A theoretical framework. *Journal of Medical Internet Research*, 22(6), e15563.

Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)* (pp. 493–502). Association for Computing Machinery. <https://doi.org/10.1145/1240624.1240704>

Zimmerman, J., Stolterman, E., & Forlizzi, J. (2010). An analysis and critique of *research through design*. *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 310–319. <https://doi.org/10.1145/1858171.1858228>

PUBLICATIONS

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Mapping Design Frameworks for Digital Behaviour Change Interventions to Goal-Directed Design

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Abstract— The use of Digital Behaviour Change Interventions (DBCIs) to form, alter, and maintain health-related behaviour is increasing in people's daily lives. Designing DBCIs for health behaviour change requires contributions from both behaviour intervention designers and interaction designers. Intervention Design (INTD) is a well-established psychological practice that guides the process of designing behaviour change interventions based on psychological theory. Interaction Design (IxD) helps design a digital product's overall structure and interactive behaviour, typically in line to the user's preferences, needs, and goals. IxD approaches such as Activity-Centred Design, User-Centred Design, and Goal-Directed Design (GDD) are used to facilitate the design process of digital products. While several frameworks are proposed to design DBCIs for health behaviour change, it is still unclear to what extent INTD and IxD approaches are integrated into these DBCIs for health behaviour change. The current paper aims to use GDD as a referential model to map existing frameworks of DBCIs for health behaviour change to identify to what extent and how these frameworks guide the combining INTD and IxD processes. Results indicate that all DBCIs for health behaviour change frameworks include the INTD phase. The specific IxD methods such as user research, prototyping and usability testing are reported more frequently in frameworks for designing DBCIs. None of the frameworks for designing DBCI for health behaviour change implemented any structured IxD frameworks. The absence of clear guidance for IxD designers who aim to design DBCI for health behaviour change represents a knowledge gap in the field of IxD. More guidelines on IxD methodology are needed to integrate IxD methods with INTD for designing effective DBCIs for health behaviour change.

Keywords — *interaction design, digital behaviour change interventions, health behaviour change*

I. INTRODUCTION

A. Problem Statement

The use of technologies, such as wearables, mobile applications and services, is rapidly increasing in people's daily lives [1]–[3]. These technologies can support health behaviour change by helping to form, alter, or maintain health-related behaviours and are referred to as Digital Behaviour-Change interventions (DBCIs) [1], [4]–[6]. The design of DBCIs is challenging and requires contributions from multidisciplinary fields, particularly behaviour *Intervention Design* and *Interaction Design* [7], [8].

“*Intervention Design* (INTD)” guides the process of designing theory-based interventions. It mainly includes the process of identifying psychological needs and the selection of appropriate theory-based behaviour change techniques [9]. Behaviour Change techniques are the mechanisms of change (e.g., prompts and cues, self-monitoring of behaviour) to support behaviour change. Several theories, frameworks and models, e.g., the *Medical Research Council* [10], the

Framework for Developing and Evaluating Complex Interventions [3], and the *Behaviour Change Wheel* [9] have already been proposed to design theory-based behaviour change interventions. Michie et al. [9] provided a comprehensive list of 93 behaviour change techniques that can be utilised according to a person's specific needs. However, existing behaviour change frameworks and models mainly support face-to-face therapeutic settings and provide no information about translating theoretical knowledge into design features of DBCIs.

“*Interaction Design* (IxD)” is focused on designing the overall structure and interactive behaviour of the digital product [11]. Several IxD methods (e.g., ethnographic interviewing, personas, scenarios, storyboards, prototyping, methods for usability testing, etc.) have been proposed to facilitate this process of designing the user-centred interactive behaviour of the system. Modern popular IxD approaches, such as System-Centred Design, Activity-Centred Design, User-Centred Design and *Goal-Directed Design* (GDD), provide consequences of IxD methods organised in the design processes of digital products [12]–[14]. Based on the situation, the designers can select one or a combination of approaches for their design needs [14]. The System-Centred Design approach is focused on designing components and functionality of the digital product to achieve system goals. The Activity-Centred Design approach focuses on designing tools and solutions to help users accomplish specific activities. The User-Centred Design approach considers user needs, preferences, and limitations while designing digital products and involves users in the design process [12], [13]. The GDD approach is based on a User-Centred Design approach that provides a structured, detailed process for designing digital products to achieve specific user goals. The GDD approach is focused on understanding user goals, understanding user requirements, and designing the digital product's form (high or low-resolution screen), posture (how much attention the user devotes to the product), and input methods (how the user will interact with the product). It requires more understanding of the user's relationship with the product and the user's needs, motivations, and goals [15] and, because of that, has the potential to be used for behaviour change applications.

The overall design of DBCIs for health behaviour change is complex and needs to consider the user's needs and requirements to achieve their specific health behaviour change goals by using appropriate behaviour change techniques. Different frameworks of DBCIs have been proposed to integrate IxD methods with INTD. For example, IDEAS (*Integrate, Design, Assess and Share*) [16] Framework, a framework for Youth-Centred digital interventions [17], and TUDER (*Targeting, Understanding, Designing, Evaluating and Refining*) [18] guide integrating theoretical knowledge of behaviour change with IxD methods. However, the level of integration of INTD and IxD in these frameworks for

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designing DBCIs for health behaviour change is unclear. The current paper aims to use GDD as a referential model to map existing frameworks of DBCIs for health behaviour change to identify to what extent and how these frameworks guide the combining INTD and IxD processes. As DBCIs are goal-driven (focused on achieving user's health behaviour change goals), the GDD approach can be used as a referential IxD approach to map existing frameworks of DBCIs for health behaviour change. Understanding the *integration levels of these approaches* should contribute to the IxD field by identifying the potential knowledge gap, limitations, and challenges related to digital design for behaviour change.

B. Research Questions

Research questions for the current study are:

- What are the existing frameworks for designing digital behaviour change interventions for health behaviour change?
- How and to what extent interaction and intervention design are integrated into the existing DBCI frameworks?

C. Goal-Directed Design

Goal-Directed Design (GDD) is a User-Centred Design approach that supports designing interactions between users and systems [12], [13], [15] by prioritising the user's needs and goals. The GDD method ensures that interactions are designed with purpose and intention, leading to a more meaningful dialogue/interaction between the user and the product [12], [13], [15] to achieve the user's goals. GDD is the most detailed and structured approach, which provides a systematic way of understanding user needs and requirements and translating them into the design of digital products. Fig. 1 presents an overview of the GDD approach and phases.

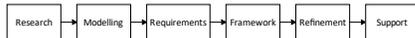


Fig. 1. Goal-Directed Design

The *Research Phase* involves gathering knowledge about the user, i.e., when and how the product will be used, the user's needs, goals and motivation, the user's understating of their jobs, expectations from the product, problems and frustrations with the current products. The *Research Phase* involves conducting qualitative studies to understand users' needs, goals and motivations through focus groups, interviews, and ethnographic studies. The *Modelling Phase* involves creating descriptive models of users based on research called "personas" [15]. According to Cooper et al. [15], the persona is the basic IxD method that represents the user throughout the design process and provides precise descriptions of different types of users, users' values, goals, and behaviour patterns.

The *Requirements Phase* involves developing scenarios and identifying user requirements. The scenarios help to describe how users interact with the technology. The *Requirements Phase* further involves identifying user requirements (e.g., functional needs) based on the persona's goals. The *Requirements Phase* helps to define what a product should be and what products should do.

The *Framework Phase* [12], [15] primarily focuses on how the product behaves and how it is structured to meet user

goals. The *Framework Phase* is focused on defining the interaction framework for the digital product, and it involves:

- Defining form factor (i.e., high or low-resolution screen), posture (i.e., attention the user will devote to the product and product behaviour), and input methods (i.e., how the user interacts with the product);
- Defining data elements (i.e., fundamental subjects of interactions, e.g., email, photos) and functional elements (i.e., operations on data elements);
- Determining functional groups and hierarchy (i.e., organising data and functions into screens, panes etc.);
- Sketching the interaction framework (i.e., iteratively sketching the interaction framework);
- Constructing key path scenarios (i.e., describing how personas will interact with the product);
- Checking designs with validation scenarios, e.g., alternative, necessary use, and edge case scenarios.

Lastly, the *Refinement Phase* includes refining the product's form and behaviour and translating the product into high-resolution screens. Various usability and heuristic evaluation types can be conducted during this phase to refine the product. As mentioned earlier, DBCIs are goal-driven (focused on achieving users' health-related behaviour change goals). This paper uses GDD as a referential model to map existing frameworks for DBCIs for health behaviour change with IxD methods.

II. RELATED WORKS

We did not find any specific study which attempted to map frameworks for designing DBCIs for health behaviour change with IxD methods. However, some studies highlighted the need to utilise design approaches, e.g., user-centred design, in designing DBCIs [19], [20]. For example, Korpershoek [21] developed an application to support self-management in patients diagnosed with obstructive pulmonary disease by combining INTD with the User-Centred Design approach. Wray et al. [22] developed an application to reduce risky health behaviours based also on the User-Centred Design approach. Thus, it is important to understand how frameworks for designing DBCIs for health behaviour change guide the integration of Interaction design frameworks with INTD.

III. METHOD

The current review only includes frameworks that provide such concepts as design phases, process guidelines, and aim design of DBCIs for health behaviour change. Frameworks were excluded if they did not specifically focus on designing digital behaviour change interventions. For example, *Information and Communications Technology-based Interventions targeting Patient Empowerment* [23] were excluded as they focused on patient empowerment rather than behaviour change. Frameworks focused only on behaviour change process theories rather than the design of DBCIs were also excluded. For example, O'Raghallaigh [24] proposed a framework focused on how to utilise different behaviour change techniques (e.g., education) across different stages of change (e.g., contemplation stage) according to transtheoretical model of health behaviour change [25] to achieve intervention goals (e.g., capability). However, the study does not aim DBCI and was not included. Overall, eight

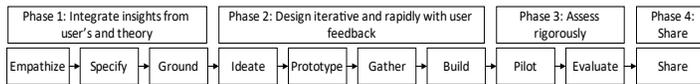


Fig. 2. IDEAS Framework [16]

frameworks for designing DBCIs for health behaviour change were included in the current review.

IV. RESULTS

The result section provides an overview of the frameworks' design process/phases and mapping with GDD. The results are divided into two sections: A: Overview of the frameworks for designing DBCIs for health behaviour change, and B: Mapping of frameworks for Designing DBCIs for health behaviour change with Goal-Directed Design.

A. Overview of the frameworks for designing DBCIs for health behaviour change

Eight frameworks were identified for designing DBCIs for health behaviour change. This section will provide an overview of the included frameworks and the inclusion of IxD methods in the frameworks.

1) *IDEAS Framework (Integrate, Design, Assess, Share)*: IDEAS [16] framework, up to now, seems like a most holistic attempt to combine IxD practices and INTD for behaviour change. It consists of four main phases, as shown in Fig. 2. The *Integrate Phase* involves selecting the target behaviours for change and grounding interventions into behaviour change theories. It suggests exploring the user's psychological and behavioural needs, motivations, and challenges related to behaviour change. The *Design Phase* involves multiple iterative brainstorming sessions to strategies behaviour change techniques in DBCIs for health behaviour change. This phase involves iteratively ideating and designing lo-fi prototyping and gathering user feedback. The *Assess Phase* is focused on evaluating the system's usability, feasibility, and potential efficacy to refine the product, and conducting randomised controlled trials. The *Share Phase* is focused on sharing knowledge and results through publications/conferences.

The IDEAS framework emphasised integrating insights from behaviour change theories in the first phase (*Integrate Phase*) to develop theory-based DBCIs. The authors have proposed several IxD methods for designing rough prototypes, e.g., hand sketches, mock-ups, and clickable prototypes in the *Design Phase* (prototypes). It is focused on ideating different options for strategising theory-based behaviour change techniques in DBCIs.

The description in the *Prototype Phase* is not elaborated enough to map with the GDD method (i.e., sketching the interaction framework). GDD focuses on defining the product's interaction framework (*Framework Phase*), i.e., specification of form, posture, behaviour, and functional groups of the product before sketching the interaction framework. Sketching the interaction framework involves sketching pre-defined functional groups and related descriptions. IDEAS framework does not provide details on

defining the product's interaction framework, which is important for sketching the interaction framework.

Moreover, the IDEAS [16] framework has mentioned gathering user feedback in the *Gather Phase* on prototypes using IxD methods such as usability testing, interviews, and surveys. *Usability testing* is a significant IxD activity, briefly mentioned in the IDEAS framework. The authors mentioned separate IxD methods e.g., prototype in difference phases but did not refer to any structured IxD approach.

2) *SATO (IDEAS exPanded with BCIO): Workflow for Designers of Patient-Centred Mobile Health Behaviour Change Intervention Applications*: SATO [26] framework extends the IDEAS framework [16]. It integrated BICO (Behaviour Change Intervention Ontology) in the first phase of the IDEAS framework (integrate insights from users and theory). BICO provides a systematic way to characterise behaviour change interventions, their contexts, and their evaluations. BICO involves describing behaviour change intervention scenario (understanding the content and creating user personas, designing clinical goals, and lag measures), identifying multiple behaviour change interventions for clinical goals, creating behaviour change intervention content (creating user stories, intervention protocols and sources, selecting behaviour change techniques, and perform behaviour change intervention tailoring (Customise and personalise interventions). Fig. 3 shows the extension of the IDEAS framework with BICO.

SATO framework mentions understanding the population and setting for intervention based on user personas (*describe behaviour change intervention scenario*); however, it does not define or elaborate on the process of designing the persona itself. Moreover, SATO mentions developing user stories (*creating behaviour change intervention content*) to help designers identify obstacles the users may face while using the digital product. SATO referred to IxD methods persona and user stories; however, the descriptions are insufficient to map with GDD Method (i.e., Persona and Scenario). SATO framework did not refer to or utilise any structured IxD approach.

3) *TUDER Framework (Targeting, Understanding, Designing, Evaluating, Refining)*: TUDER framework [18] consists of four phases presented in Fig. 4. The Targeting and Understanding Phases focus on selecting a target user group, health behaviour for change, and behaviour change techniques based on behaviour change theories. The Design Phase focuses on designing strategies to implement behaviour change techniques through digital technologies and workflows to deliver interventions according to time (e.g., hourly reminders), events (food recommendations according to the *previous meal*) or based on *specific tasks* [27].

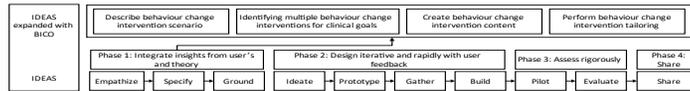


Fig. 3. SATO Framework [26]

The Evaluation *and* Refining Phases involves iterative evaluation of prototypes (heuristic evaluation, cognitive walkthrough and think-aloud tests to uncover potential issues and barriers), piloting the DBCIs for health behaviour change, and conducting clinical trials.

It involves evaluating user experience, usability, acceptability, appropriateness of content delivery, and barriers in usage and implantation of intervention. Lastly, improving the intervention based on results involves promoting the intervention and exploring the effectiveness of the intervention in larger target groups.

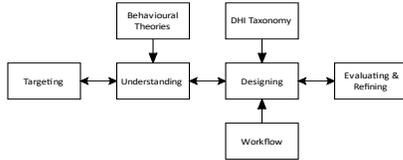


Fig. 4. TUDER Framework [18]

The TUDER framework emphasised integrating insights from behaviour change theories in the *Targeting* and *Understanding* phases to develop theory-based DBCIs. The *Designing* Phase only involved designing digital methods and workflows for delivering behaviour change techniques, which cannot be mapped with GDD methods. Moreover, many IxD methods (evaluating prototypes using heuristic evaluation, cognitive walkthrough, and think-aloud tests) were mentioned in the *Refining* Phase; however, no specific guidelines and processes related to using these IxD methods were mentioned. The authors have mentioned different methods for usability testing. However, the authors did not mention any structured IxD approach to use IxD methods for designing DBCIs for health behaviour change.

The framework provides detailed guidelines for identifying users' psychological and technological needs that can be mapped with the *Research* phase of GDD. Further, authors [17] mentioned IxD methods such as persona and prototyping (*Developing* Phase). However, they did not provide enough guidelines to help designers capture findings from the *Research* Phase to use them for designing persona and prototyping. The authors have mentioned some IxD methods (persona, prototyping) but neither referred to nor utilised any structured IxD approach to design DBCIs.

4) *Framework for Designing Youth-Centred Digital Interventions*: The framework for designing Youth-Centred digital interventions [17] suggested three phases of designing DBCIs presented in Fig. 5. The *Planning* Phase involves reviewing the literature to gather evidence on existing digital and non-digital interventions. It includes understanding individuals' needs (interests, digital literacy, and technological preferences), interpersonal needs (e.g., family environment/social influences etc.), community needs, and public policy (existing health policies). The *Developing* Phase includes developing content and delivery strategies. It includes identifying different user personas, determining frequency, dosage, the language of the content delivery, and determining how the content will be managed. This phase also mentions co-design methods to design content with the target groups. Next, it involves creating a series of prototypes and gathering early user feedback.

5) *Behavioural Intervention Technology Model (BIT Model)*: The BIT model consists of two major phases, i.e., the theoretical phase and the instantiation phase [27]. The *Theoretical* Phase comprised selecting intervention targets for behaviour change and selecting behaviour change techniques. The *Instantiation* Phase involves selecting elements, characteristics, and workflow. Elements can support the delivery of behaviour change techniques, such as notifications, logs, data collection methods, reports etc. Characteristics include the selection of medium (text, video, or audio), complexity level according to the capabilities and limitations of the user target group (e.g., elaborative vs. leaner content), aesthetics, and personalisation according to pre-defined criteria. The workflow defines when and under what conditions behaviour change techniques would be delivered. It can be time (e.g., an hourly reminder), event (food recommendation according to the previous meal), or task-based decision. Overall, BIT does not provide any descriptions and guidelines that could be mapped to existing IxD methods.

The *Implementation* Phase involves a phased launch of the DBCIs into a real-world setting before a full-scale launch.

6) *The Adaptive Behavioural Components (ABC) Model for Planning Longitudinal Behavioural Technology-Based Health Interventions: a Theoretical Framework*: ABC Model [28] is based on five factors essential to designing Digital interventions for behaviour change. i., selecting and integrating behaviour change components based on behaviour change theories, e.g., developing intrinsic motivation, planning incremental change, making the new behaviour easy to engage with etc. ii., tailoring intervention according to specific barriers preventing people from engaging in the behaviours, e.g., individual beliefs, forgetfulness etc. iii., tailoring information content according to people culture and environment, e.g., creating culturally adaptive interventions, iv., tailoring according to individual levels, e.g., consideration to people personality traits can increase intervention efficacy, v., considering type of the technology (e.g., audio or video), features of technology (e.g., adding an online community



Fig. 5. Youth-Centred Framework [17]

feature), and ethical issues related to technology usage. Overall, the ABC model highlights factors to be considered when designing DBCIs for health behaviour change but does not provide any phases or processes to design DBCIs. ABC model briefly mentioned considering technology characteristics for delivering behaviour change interventions but does not provide any information on specific IxD methods or approaches.

7) *A Design and Evaluation Framework for Digital Health Interventions (DEDHI framework)*: The Design and Evaluation Framework [29] mentioned three phases of designing Digital health intervention and recommended relevant evaluation criteria barriers for each phase. The *Preparation Phase* is focused on defining conceptual and technological foundations, e.g., reviewing existing knowledge and developing a conceptual model of the intervention (target behaviour and behaviour change techniques). The authors [29] suggested developing a prototype with basic functionality to conduct feasibility testing. The *Optimisation Phase* focuses on conducting micro-randomised controlled trials to optimise interventions and identify the best configuration for DBCIs for health behaviour change. If any intervention component is ineffective at this stage, the researchers need to revisit the *Preparation Phase*. This phase aims to have a prototype with full functionality. Lastly, according to the conceptual model DHI, the *Evaluation Phase* focuses on randomised controlled trials to evaluate the effectiveness and full functionality. However, randomised controlled trials are outside of the scope of IxD methods. The authors have also elaborated on some implementation and evaluation barriers. Overall, The DEDHI did not provide information on integrating any existing IxD approach in designing DBCIs.

8) *Framework for DBCIs: An Iterative, Interdisciplinary And Collaborative Approach Combining Behaviour Science, Human-Centred Design, And Data Science*: This framework is based on the agile approach, human-centred design, and behavioural intervention design [30]. It comprises five stages (Pre-define, Define, Design, Develop and Deploy), as presented in Fig. 6.

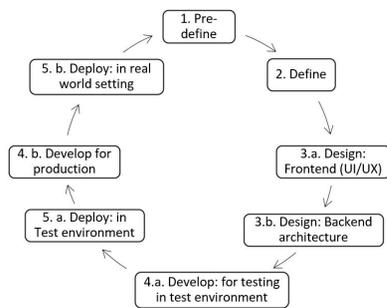


Fig. 6. Framework for DBCIs: An Iterative, Interdisciplinary And Collaborative Approach Combining Behaviour Science, Human-Centred Design, And Data Science [30]

The *Pre-define Phase* is based on conducting user research, i.e., understanding target groups, health behaviours, and user's context of technology usage (e.g., how the digital intervention fits with the user's health and daily routines). The *Define Phase* is based on selecting behaviour change techniques for behaviour change and designing intervention strategies. The *Design Phase* involves *front-end* design and *back-end* design. The *Front-End Design Phase* is intended to enable designers to map user interaction and design features against the specific scientific requirements of behaviour change techniques. This *Phase* involves designing wireframes/prototypes and usability testing. *Back-end* design involves designing system architecture. The *Develop* and *Deploy Phases* involve developing minimum viable products, iterative testing with test users, and developing and deploying in real-world settings. This framework explicitly mentions iterative design processes and multidisciplinary collaboration at each stage (Fig. 6). In the *Front-End Design Phase*, the framework mentions several IxD methods (user research, user journeys, prototypes, wireframes, and usability testing). However, it did not provide any definitions or descriptions on how these IxD methods can be used to design DBCI.

B. Mapping of Frameworks for Designing DBCIs with Goal-Directed Design

This review explored how and to what extent IxD methods are combined with INTD in the existing frameworks for designing DBCIs for health behaviour change. GDD framework was used as a referential model to map existing frameworks of designing DBCIs for health behaviour change. Table I indicates how GDD phases (*Research, Modelling, Requirements Definition, Framework Definition, Refinement, and Support*) are combined with INTD. All DBCI frameworks considered INTD as the first phase in the design process. Mapping of the frameworks with GDD was done on the basis of i., if the IxD method is mentioned in the frameworks, and ii., how much elaboration is presented in the framework. Table I indicates boxes with if the descriptions is presented with enough elaboration to be mapped as IxD methods was marked as Described, However, if only IxD method is named without enough elaboration to be mapped as IxD methods was marked as Non Described in Table I.

Overall, frameworks for designing DBCIs for health behaviour change mentioned some IxD methods, but none specified any particular structured IxD approaches. The GDD Research Phase was mentioned in two frameworks (Youth-Centred framework, Framework for designing DBCIs) [17], [30] but described in detail only in the Youth-Centred framework [17]. However, these frameworks do not mention how findings from user research insights can be used further in the design process. Youth-Centred framework [17], SATO [26] mentioned designing user personas; however, they do not provide any process for capturing insights from user research to design user personas or how personas can be used in the further design process. IDEAS [16], Youth-Centred framework [17], and framework for DBCIs [30], mentioned designing prototypes of the potential DBCIs, but this cannot be directly mapped with the *Framework Phase* of GDD because the authors did not elaborate on designing the Interaction framework (*Framework Phase*) of the digital product, i.e., form, posture, input methods and functional groups of the product.

TABLE I. MAPPING OF FRAMEWORKS FOR DESIGNING DBCIS WITH GOAL-DIRECTED DESIGN

Design	Phase	Methods	Frameworks for Designing DBCIs for Health Behavior Change							
			<i>Mummah et al., [16]</i>	<i>Lisowska et al., [26]</i>	<i>Wang et al., [18]</i>	<i>World Health [17]</i>	<i>Mohr et al., [27]</i>	<i>Young [28]</i>	<i>Kowatsch et al., [29]</i>	<i>Sucala et al., [30]</i>
Intervention Design	Theory based Intervention		Described	Described	Described	Described	Described	Described	Described	Described
Goal Directed Design	Research	User Research				Described				Non-Described
	Modelling	Persona		Non-Described		Non-Described				
	Requirements	Scenario		Non-Described						
		Requirements								
	Framework	Defining form, factor posture & Input methods								
		Determine functional groups and hierarchy								
		Sketch the interaction framework	Non-Described			Non-described				Non-Described
		Construct key path scenarios								
		Check designs with validation Scenarios								
	Refinement	Developing high resolution screen	Described							
Usability testing		Non-Described	Non-Described	Non-Described	Non-Described				Non-Described	
Support	Support									

Some frameworks, such as IDEAS [16], SATO [26], TUDAR [18], Youth-Centred Framework [17], and The Design and Evaluation Framework [29], focused on conducting *Usability testing* of the prototypes and mentioned some IxD methods (heuristic evaluation, think loud tests, cognitive walkthrough); however, they do not provide enough descriptions for the designers on selecting and using specific IxD method for usability testing. Even though all frameworks positioned themselves as frameworks for designing digital products they did not mention any specific digital tools (wearables, mobile application etc.) for implementation.

Overall, the results indicate that specific IxD methods such as user research, prototyping and usability testing are reported more frequently in frameworks for designing DBCIs for Health Behaviour Change. In most cases, frameworks just named some IxD methods [30] but did not provide any specific information on how IxD methods could be combined as a structured approach or process for designing the interactive behaviour of the DBCIs. None of the frameworks for designing DBC for health behaviour change implemented a structured IxD approach.

V. CONCLUSION

The paper reviewed how IxD methods are combined with INTD in existing frameworks for designing DBCIs for health behaviour change. Recent advancements in technology led to increased use of technologies for health behaviour change.

The knowledge of behaviour change is predominantly based on theories of behaviour change which need to be appropriately translated into the design of DBCIs for health behaviour change to achieve users' health-related goals. Designing of interactive behaviour of the system to achieve the user's goals is guided by IxD.

The results highlighted that the current frameworks for designing DBCIs for health behaviour change focused on including INTD in the design process of DBCIs. Currently, many theories, models and frameworks are available that guide the process of designing theory-based interventions. However, the current frameworks lack integration of IxD approaches in the design process of DBCIs. Certain frameworks for designing DBCIs for health behaviour change mention some IxD methods; however, they do not mention any structured IxD approach for designing DBCIs. Moreover, the guidelines are not specific enough to help designers use specific IxD methods for designing DBCIs, for health behaviour change, e.g., how to design personas based on user research. This lack of inclusion and description of IxD methods and frameworks represents a knowledge gap in the field of IxD and a challenge for interaction designers to design DBCIs for health behaviour change. More work on specific methodological frameworks and guidelines is needed to integrate IxD approaches with DBCIs for health behaviour change. Addressing this gap can enhance the quality of DBCI design, prioritise user needs, and advance the IxD field.

REFERENCES

- [1] E. B. Hehler et al., "Advancing Models and Theories for Digital Behavior Change Interventions," *Am J Prev Med*, vol. 51, no. 5, pp. 825–832, Nov. 2016, doi: 10.1016/j.amepre.2016.06.013.
- [2] H. Oinas-Kukkonen, "Behavior change support systems: A research model and agenda." Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 6137 LNCS, pp. 4–14, 2010, doi: 10.1007/978-3-642-13226-1_3/COVER.
- [3] K. Skivington et al., "A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance," *BMJ*, vol. 374, Sep. 2021, doi: 10.1136/bmj.n2061.
- [4] L. Yardley, T. Choudhury, K. Patrick, and S. Michie, "Current Issues and Future Directions for Research Into Digital Behavior Change Interventions," *Am J Prev Med*, vol. 51, no. 5, pp. 814–815, Nov. 2016, doi: 10.1016/j.amepre.2016.07.019.
- [5] S. Michie, L. Yardley, R. West, K. Patrick, and F. Greaves, "Developing and Evaluating Digital Interventions to Promote Behavior Change in Health and Health Care: Recommendations Resulting From an International Workshop," *J Med Internet Res* 2017;19(6):e232 <https://www.jmir.org/2017/6/e232>, vol. 19, no. 6, p. e7126, Jun. 2017, doi: 10.2196/JMIR.7126
- [6] H. Oinas-Kukkonen, K. T. Win, and S. Chatterjee, "Introduction to health behavior change support systems (HBCSS) minitrack," *Proceedings of the Annual Hawaii International Conference on System Sciences*, vol. 2016-March, p. 3073, Mar. 2016, doi: 10.1109/HICSS.2016.386
- [7] A. C. Moller et al., "Applying and advancing behavior change theories and techniques in the context of a digital health revolution: proposals for more effectively realising untapped potential," *J Behav Med*, vol. 40, no. 1, pp. 85–98, Feb. 2017, doi: 10.1007/S10865-016-9818-7.
- [8] P. Voorheis et al., "Integrating Behavioral Science and Design Thinking to Develop Mobile Health Interventions: Systematic Scoping Review," *JMIR mhealth Uhealth*, vol. 10, no. 3, Mar. 2022, doi: 10.2196/35799.
- [9] S. Michie et al., "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*, vol. 46, no. 1, pp. 81–95, Aug. 2013, doi: 10.1007/S12160-013-9486-6.
- [10] P. Craig, P. Dieppe, S. Macintyre, S. Mitchie, I. Nazareth, and M. Petticrew, "Developing and evaluating complex interventions: The new Medical Research Council guidance," *Bmj*, vol. 337, no. 7676, BMJ Publishing Group, pp. 979–983, Oct. 25, 2008, doi: 10.1136/bmj.a1655.
- [11] M. Jones and G. Marsden, "Watching, asking, probing," *Mobile Interaction Design*, pp. 121–168, 2006, Accessed: Jun. 13, 2023. [Online]. Available: <https://www.wiley.com/en-us/Mobile+Interaction+Design-p-9780470090893>
- [12] A. Williams, "User-centered design, activity-centered design, and goal-directed design: A review of three methods for designing web applications," *SIGDOC'09 - Proceedings of the 27th ACM International Conference on Design of Communication*, pp. 1–8, 2009, doi: 10.1145/1621995.1621997.
- [13] C. Wei and F. Xing, "The comparison of user-centered design and goal-directed design," *2010 IEEE 11th International Conference on Computer-Aided Industrial Design and Conceptual Design, CAID and CD 2010*, vol. 1, pp. 359–360, 2010, doi: 10.1109/CAIDCD.2010.5681336.
- [14] D. Saffer, "Designing for Interaction: Creating Innovative Applications and Devices (2nd Edition) (Voices That Matter)," p. 240, 2009, Accessed: Jul. 28, 2023. [Online]. Available: https://books.google.com/books/about/Designing_for_Interaction.htm?hl=et&id=k28yVW3SEyYC
- [15] A. Cooper, R. Reimann, D. Cronin, C. Noessel, J. Csizmadi, and D. Lemoine, "About Face The Essentials of Interaction Design Fourth Edition," 2014.
- [16] S. A. Mummah, T. N. Robinson, A. C. King, C. D. Gardner, and S. Sutton, "IDEAS (integrate, design, assess, and share): A framework and toolkit of strategies for the development of more effective digital interventions to change health behavior," *J Med Internet Res*, vol. 18, no. 12, Dec. 2016, doi: 10.2196/jmir.5927.
- [17] World Health Organization, "Youth-Centred Digital Health Interventions: A framework for planning, developing, and implementing solutions with and for young people," 2020. <https://www.unfpa.org/publications/youth-centred-digital-health-interventions-framework-planning-developing-and> (accessed Jan. 12, 2023).
- [18] Y. Wang, A. Fadhil, J. P. Lange, and H. Reiterer, "Integrating Taxonomies Into Theory-Based Digital Health Interventions for Behavior Change: A Holistic Framework," *JMIR Res Protoc*, vol. 8, no. 1, Jan. 2019, doi: 10.2196/RESPROT.8055.
- [19] A. Dominguez-Rodriguez and A. de La Rosa-Gómez, "A Perspective on How User-Centered Design Could Improve the Impact of Self-Applied Psychological Interventions in Low- or Middle-Income Countries in Latin America," *Front Digit Health*, vol. 4, p. 86, Jun. 2022, doi: 10.3389/FGDH.2022.866155/BIBTEX.
- [20] L. Fleisher et al., "Using theory and user-centered design in digital health: The development of the mychoice communication tool to prepare patients and improve informed decision making regarding clinical trial participation," *Psychooncology*, vol. 29, no. 1, pp. 114–122, Jan. 2020, doi: 10.1002/PON.5254.
- [21] Y. J. G. Korpershoek, S. Hermsen, L. Schoonhoven, M. J. Schuurmans, and J. C. A. Trappenburg, "User-Centered Design of a Mobile Health Intervention to Enhance Exacerbation-Related Self-Management in Patients With Chronic Obstructive Pulmonary Disease (Copilot): Mixed Methods Study," *J Med Internet Res*, vol. 22, no. 6, Jun. 2020, doi: 10.2196/15449.
- [22] T. B. Wray, C. W. Kahler, E. M. Simpanen, and D. Operario, "User-centered, interaction design research approaches to inform the development of health risk behavior intervention technologies," *Internet Interv*, vol. 15, pp. 1–9, Mar. 2019, doi: 10.1016/J.INVENT.2018.10.002.
- [23] L. Karmi, K. Dalal, M. Medemi, D. Kalra, and G. O. Klein, "Information and Communications Technology-Based Interventions Targeting Patient Empowerment: Framework Development," *J Med Internet Res* 2020;22(8):e17459 <https://www.jmir.org/2020/8/e17459>, vol. 22, no. 8, p. e17459, Aug. 2020, doi: 10.2196/17459.
- [24] P. O'Raghallaigh and F. Adam, "A Framework for Designing Digital Health Interventions," *Journal of the Midwest Association for Information Systems*, vol. 2017, no. 2, pp. 41–56, Jul. 2017, doi: 10.17705/3JMWA.00030.
- [25] J. O. Prochaska and W. F. Velicer, "The transtheoretical model of health behavior change," *American Journal of Health Promotion*, vol. 12, no. 1, pp. 38–48, 1997, doi: 10.4278/0890-1171-12.1.38.
- [26] A. Lisowska, S. Wilk, and M. Peleg, "SATO (IDEAS expANded wiTh BCIO): Workflow for designers of patient-centered mobile health behaviour change intervention applications," *J Biomed Inform*, vol. 138, Feb. 2023, doi: 10.1016/J.JBI.2022.104276.
- [27] D. C. Mohr, S. M. Schueller, E. Montague, M. N. Burns, and P. Rashidi, "The behavioral intervention technology model: an integrated conceptual and technological framework for eHealth and mHealth interventions," *J Med Internet Res*, vol. 16, no. 6, 2014, doi: 10.2196/JMIR.3077.
- [28] S. D. Young, "The Adaptive Behavioral Components (ABC) Model for Planning Longitudinal Behavioral Technology-Based Health Interventions: A Theoretical Framework," *J Med Internet Res* 2020;22(6):e15563 <https://www.jmir.org/2020/6/e15563>, vol. 22, no. 6, p. e15563, Jun. 2020, doi: 10.2196/15563.
- [29] T. Kowatsch, L. Otto, S. Harperink, A. Cotti, and H. Schlieter, "A design and evaluation framework for digital health interventions," *IT - Information Technology*, vol. 61, no. 5–6, pp. 253–263, Oct. 2019, doi: 10.1515/itit-2019-0019.
- [30] M. Sucala, N. P. Ezeanochie, H. Cole-Lewis, and J. Turgiss, "An iterative, interdisciplinary, collaborative framework for developing and evaluating digital behavior change interventions," *Transl Behav Med*, vol. 10, no. 6, pp. 1538–1548, Dec. 2020, doi: 10.1093/TBM/IBZ109.

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Enriched with Behaviour Theory Topic Guide Template for Digital Behaviour Change Interventions

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Abstract. Interviews and focus groups are interaction design user research methods that aim to understand user needs and goals regarding the potential use of digital products. In the case of designing Digital Behaviour Change Interventions (DBCIs) for health, these methods need to be adjusted to allow explicit focus on understanding determinants that possibly influence individual health-related behaviours (for example, beliefs, motivations, social pressure). Behaviour change theories and models help to identify these determinants of influencing behaviours. However, interaction designers are not competent in having knowledge of behaviour change theories, which makes it difficult to integrate this knowledge into interaction design user research. It can limit the design for theory-based DBCIs. The current study proposed and evaluated a generic topic guide template for interaction design user research enriched with a behaviour change theory. The paper proposes guidelines for adapting and analysing the data. The proposed topic guide template was adapted to understand the needs and age-related differences of children with type I diabetes. Focus groups were conducted with parents and medical professionals. Results indicated various behaviour change-related needs of the children and highlighted age-related differences in children's skills, independence, and motivation to manage diabetes. Various behaviour change theory-based design implications for interaction design were derived. The results highlight the importance of enriching the user research methods with behaviour change theories and models for designing DBCIs for health.

Keywords: Interaction design · User research · Behaviour change theory

1 Problem Statement

Digital Behaviour Change Interventions (DBCIs) for health can support forming, altering or maintaining health-related behaviours [1–3]. Designing DBCIs for health requires contributions from multidisciplinary fields, including interaction design [4] and intervention design [5]. Intervention design involves understanding individuals' factors or determinants that influence health-related behaviours, such as beliefs, motivation, and social or peer pressure, which are based on various behaviour change theories and models [6]. This further involves the selection of appropriate behaviour change techniques (for

example, prompts and cues, rewards, and self-monitoring) [5, 7] that potentially influence determinants of behaviour to facilitate change in health behaviours. It is recommended to design behaviour change theories based DBCIs [8–11].

Interaction design primarily focuses on the structure and interactive behaviour of the digital product [4, 12, 13]. Interaction design approaches, such as User-Centered Design, focus on involving the user throughout the design process. Goal-Directed Design is an extension of User-Centered Design and provides a detailed process of designing digital products to ensure the achievement of specific user goals [4, 14, 15]. User research is conducted in the initial phases of User-Centered Design and Goal-Directed Design [4, 14, 15]. The user research methods, such as observations, interviews, and focus groups, help to understand user needs, goals, behaviours, attitudes, aptitudes, motivations (what motivates people to use products), environments (e.g., the context of technology usage), decision-making process, problems and frustrations that are caused by the current product or a comparable system for designing digital systems important for designing digital products. The user research methods address the different types of users and their needs, their behavioural patterns (e.g., frequency, desires, motivation), the user's technical expertise, and domain-related expertise (subject area-related expertise) [4]. Insights from the User Research phase inform the overall design processes by identifying different types of users and design-related requirements regarding potential digital products [4, 13].

Interaction designers use focus groups and interviews to explore when, why, and how the product fits into users' lives or work processes [4, 13], and provide an understanding of the topic in terms of the general agreement [16]. The researcher determines how and why specific points and ideas are accepted, and others are rejected based on the different viewpoints of the focus group participants. In the case of DBCIs, these methods need to be adjusted to allow explicit focus on the behavioural change-related needs of the users. It can help designers understand specific determinants influencing behaviours, which can further lead to the selection of appropriate behaviour change techniques. However, the integration of behaviour change theories is often missed in the interaction design process [17, 18]. Frameworks for designing DBCIs suggest designing theory-based interventions, but they do not provide enough guidance on the integration of this theoretical knowledge into interaction design methods [19]. It makes the results of user research less useful for DBCI than they might be because the resulting data provides fewer BC-related insights.

Qualitative methods of data collection, such as interviews and focus groups, are often conducted using tailored in-advance topic guides that supply the topics and questions related to the study themes [20, 21]. In the interaction design, topic guides are used to elicit rich and in-depth responses from participants by encouraging open-ended dialogue and exploration of ideas. The topic guides per se are more generative and, in the case of design for DBCI, are rarely theory-based [22]. In contrast, the intervention designers conduct qualitative studies based on behaviour change theories to understand determinants influencing behaviours. Intervention designers commonly develop interviews or focus group topic guides that are based on relevant behaviour change theories and models and ensure that the data collection is aligned with the theoretical concepts of the selected theory [23–25].

Designing a theory-based topic guide for DBCI requires an understanding of behaviour change theories and models. Due to the availability of various behaviour change theories, it is difficult for interaction designers to select one specific behaviour change theory or model to design a topic guide for user research [26]. In the current work, we aimed to propose a generic topic guide template for interaction design user research that can help to elicit the users' behaviour change-specific needs. We hypothesised that enriching the user research topic guide for qualitative studies (focus groups, interviews) based on behaviour change theories can help understand user determinants of behaviour and elicit design implications for DBCIs for health. The research question for the current study is: How can behaviour change theories be integrated into a topic guide for interaction designers to understand users' behaviour change-related needs when conducting user research for designing DBCIs?

2 Review of Topic Guides for Designing DBCIs for Health

In this section, both theory- and non-theory-based topic guides used to design DBCIs were reviewed. Most studies used qualitative approaches to understand user needs. Relatively few studies have published topic guides for interviews or focus groups.

The findings suggested that non-theory-based studies' topic guides attempted to explore user goals and preferred features of DBCIs [27–32]. For example, features for healthy eating, features for social support (private messages, online support groups), information presented in simple terms, options for situational eating, email reminders, tracking features, automated chatbots, etc. However, results generated from the analysis do not help to understand specific determinants of behaviour (e.g., motivation, emotions, beliefs, skills, etc.) required to design DBCIs. This primarily limits the designing of theory-based DBCIs and the selection of appropriate behaviour change techniques.

Overall, the questions in non-theory-based topic guides were focused on broader behavioural goals such as weight reduction and could be adaptable to other contexts or conditions. For example, the sample question in Fig. 1 (Sample Question: Qc & Qd) can be easily adapted to understand the needs of designing DBCIs in other healthcare contexts.

The theory-based topic guides help to identify various psychological determinants of behaviours [33–37]. The results of the interviews or focus groups are used to identify determinants of behaviour and selection of appropriate behaviour change techniques. Schnall et al. (2023) aimed to design an application for tobacco cessation based on the Health Belief Model and Fogg's functional model [35]. The topic guide itself was not directly based on the Health Belief Model (only two out of five questions covered two domains of the health belief model), and the author linked the results of the interview with the domains of the health belief model. The interview results were also linked to the two domains included in the topic guide (perceived barriers and perceived benefits). This suggests that it is important to design topic guides that are directly based on behaviour change theory to cover all major domains of theory; otherwise, important domains worth exploring might be neglected during research. Dack et al. (2019) conducted interviews to understand the needs of patients with Type II diabetes. The topic guide was based on Normalisation Process Theory and Corbin and Strauss' model). The findings were also linked with the theories, but the authors have not published the topic guide [36].

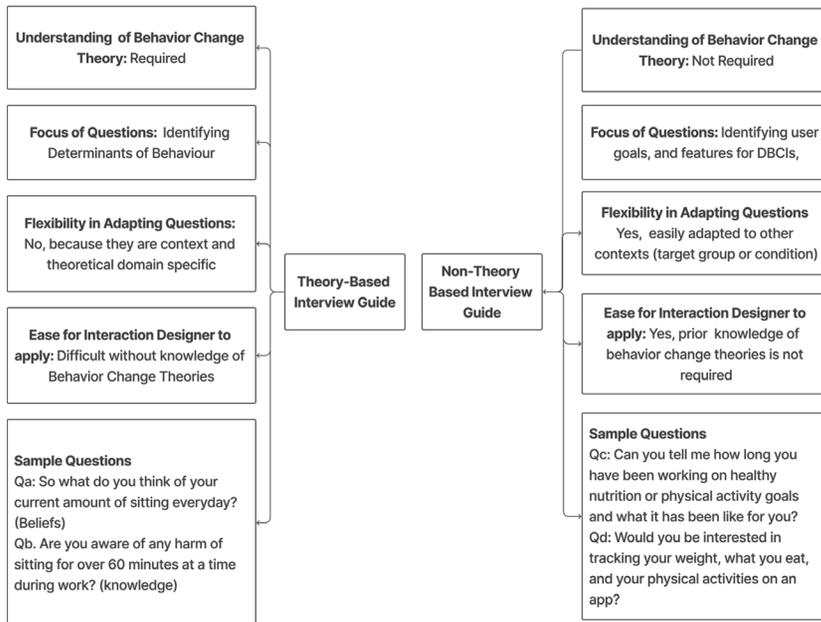


Fig. 1. Comparison of Theory and Non-Theory-Based Topic Guides.

Adapting and implanting a theory-based topic guide is difficult because questions are based on the theoretical domains or constructs of the theory and are very specific according to target behaviour. For example, questions such as “Are you aware of any harm of sitting for over 60 min at a time during work?” are very specific according to target behaviour and require answers related to particular target behaviour. It limits the applicability and adaptability of such questions in other contexts. As non-theory-based topic guides focused on identifying features of DBCIs, the features implemented in DBCIs are not directly linked with behaviour change techniques. In contrast, behaviour change techniques are selected before selecting features and thus linked with behaviour change theory and techniques.

Based on the literature review, we can conclude that non-theory-based topic guides are useful for providing user goals and preferred features for DBCIs but cannot be directly linked with individual determinants of behaviour change techniques. Meanwhile, theory-based interview topic guides provide better support for identifying determinants of behaviour and selecting behaviour change techniques according to those determinants. Designing a theory-based topic guide requires an understanding of behaviour change theories. It is important to note that no structured topic is typically used to understand individual needs. Intervention designers already know and understand behaviour change theories and intervention design processes, so it is easy for them to select a particular theory and use it to understand behaviour determinants. However, it is challenging for interaction designers to know various behaviour change theories, to select and apply them for supporting the behaviour needs of the users.

The purpose of the current study is to provide a generic behaviour change theory topic guide template that could be easily applicable and adaptable to various contexts.

3 Theory-Based Topic Guide Template for User Research

This section provides a brief overview of behaviour change theories, a comprehensive theory-enriched topic guide template for eliciting rich, relevant data needed to design DBCIs.

3.1 Behaviour Change Theories and Intervention Design Research

Behaviour change theories are founded on the idea that individual, social, and environmental factors will dynamically change and interact to influence behaviour [1], and up to 83 behaviour change theories have been proposed in the field of behaviour change [6]. For example, the theory of planned behaviour emphasises the role of individuals' positive or negative attitudes towards health-related behaviour, social norms (social expectations, peer influences, social support) and individual perceived control for determining individuals' behaviours [38]. Some theories study behaviour change as people's gradual progression through discrete stages of change, such as the transtheoretical Model [39] and the Precaution Adoption Process Model [40].

It is challenging for designers to select one specific behaviour change theory from the range of behaviour change theories [41]. Michie et al. [42] proposed the COM-B (Capability, Opportunity and Motivation -Behaviour model) model, which combined various theories of behaviour change, making it more useful for interaction designers to apply when designing DCBIs for health. We aimed to use the COM-B model to design a theory-based topic guide template for interaction designers [42]. COM-B helps to consider various determinants of behaviour (for example, physical skills, knowledge, resilience, memory, availability of time and resources, motivation, and emotional beliefs) compared to other theories, such as the theory of planned behaviour (which only focuses on attitude, social norms and perceived behaviour control) [43]. More details about the COM-B model are presented below.

COM-B Model. Cane et al. [44] combined thirty-three theories of health behaviour change (twenty-eight determinants of behaviours) into fourteen domains published as Theoretical Domain Framework (TDF). Later, these fourteen domains were further classified into three key components [42]: Capability (C), Opportunity (O), and Motivation (M), referred to as the COM-B model. Each component is further divided into two subcategories encapsulating the fourteen domains of the TDF (Table 1). For example, the knowledge domain in TDF is the part of "psychological capability" in COM-B along with other TDF domains such as memory, decision-making process, etc.

Table 1. Description of COM-B Components.

COM-B Components	Description
 Capability	<ul style="list-style-type: none"> • Physical capability refers to an individual's physical skills and abilities to perform a behaviour (TDF domains: physical skills) • Psychological capability encompasses cognitive resources, knowledge, and understanding necessary to perform a behaviour (TDF domains: knowledge, memory, attention and decision-making processes, behavioural regulation)
 Opportunity	<ul style="list-style-type: none"> • Social opportunity pertains to the external influences and social norms that facilitate or hinder behaviour (TDF domains: social influences, e.g. norms, social pressures) • Physical opportunity involves environmental factors and resources that enable behaviour enactment (TDF domains: environmental context and resources, e.g., time and money)
 Motivation	<ul style="list-style-type: none"> • Reflective motivation represents conscious intentions, goals, and belief about abilities and consequences that drive behaviour (TDF domains: Belief about capability, belief about consequences, roles and identity, intention to perform behaviour, goals, optimism) • Automatic motivation involves automatic responses, emotions, and habits and routines that influence behaviour (TDF domains: emotions, reinforcement)

Michie et al. [7] proposed three stages for developing behaviour change interventions. The first stage (*understanding the target behaviour*) involves conducting qualitative studies to identify determinants influencing behaviours based on the COM-B model. The Intervention Design begins with an in-depth understanding of individual needs, focusing specifically on exploring the determinants that influence behaviours. We assume that interaction design experts can adopt a similar approach when conducting user research by leveraging the knowledge of behaviour change theories. To support this goal, the study aimed to develop a comprehensive topic guide template based on the COM-B model for interaction design. The guide template is intended to help designers understand the determinants influencing behaviour and design DBCIs.

The second stage (*identifying intervention options*) is based on selecting appropriate intervention functions, i.e., broad categories by which an intervention can change behaviour (e.g., education, persuasion, training, etc.). The third stage (*identifying behaviour change techniques, content and implementation options*) focuses on selecting appropriate behaviour change techniques that can support the behaviour change process. Michie et al. [45] Developed the taxonomy of ninety-three behavioural change techniques, which can be selected according to the appropriate psychological needs of the users. These behaviour change techniques are later strategised into DBCIs to support behaviour change. Another advantage of selecting the COM-B model is that results can be directly linked with the selection of behaviour change techniques [43] following the second and third stages.

3.2 Enriching Interaction Design User Research Topic Guide with COM-B Model

COM-B model was introduced in the topic guide for conducting focus groups or interviews (Table 2). Literature on user research, psychology, and behaviour change provided the foundational knowledge required to design questions for the topic guide template [46]. Relevant previous literature is consulted to design a generic topic guide template for the current study [7, 33, 34, 47]. The questions for the topic guide were developed through an iterative process involving multiple rounds of drafting and refinement. Consultations with experts in intervention design and interaction design were integral to this process.

Each question is directly relevant to the COM-B components, sub-components and related TDF domains. For instance, psychological capability-related questions will help elicit responses that will directly guide and help understand the psychological capability-related needs of the users. Identified needs will further help in deriving design implications (these implications suggest how design decisions need to be made to address identified needs, challenges, or opportunities) corresponding to each COM component. It is intended to allow designers to understand user behaviour change-related needs more holistically (understanding various theory guide determinants that can influence behaviours) and structurally (eliciting responses that relate to COM-B components).

The questions are designed to be flexible and adaptable to fit different health behaviours. For example, questions such as: What kind of mental skills are required, e.g., the ability to resist urges, keep things in mind (nor forget) and make appropriate decisions to [perform specific behaviour]? can be easily adapted to fit various health-related behaviours (going for a walk, eating healthy food, counting calories).

The proposed questions in the topic guide template can be used as a base and adapted for different target populations. For example, questions directed at parents or healthcare professionals to help understand their children's or patients' needs can be adapted as "Do your children or patients have the knowledge required to [perform specific behaviour]?". Similarly, the questions can be adapted to compare user needs of different groups, such as differences in age groups (such as the difference in knowledge of children, adolescents and adults) and employment status (needs of working, non-working and freelancers, etc.).

Questions can be adapted according to literacy level (providing examples and more explanation of the questions, if needed) and cultural background. It is recommended that the adapted topic guide be pilot-tested with a small sample of users to identify any issues or areas for improvement. If needed, refine the wording, structure, and flow of the questions. Interaction designers can include probing questions and follow-up prompts to delve deeper into specific areas of interest or concern identified during the interview.

Table 2. Theory Enriched Topic Guide Template for Interaction Designers.

COM-B -Based Questions		Purpose
	Physical Capability <ul style="list-style-type: none"> What are the different physical skills or abilities (physical strength, stamina) required to perform [perform specific behaviour]? Do you have those skills? Are there any physical health conditions or limitations that affect your ability to perform certain tasks related to [perform specific behaviour]? 	Intended to support an understanding of physical limitations and capabilities that can influence behaviour.
	Psychological Capability <ul style="list-style-type: none"> What kind of knowledge is required to [perform specific behaviour]? Do you have the knowledge required to [perform specific behaviour]? What kind of mental skills are required, such as., the ability to resist urges, keep things in mind (nor forget) and make appropriate decisions to [perform specific behaviour]? Do you have those mental skills to [perform specific behaviour]? <p>The interviewer can break down questions into sub-questions focusing on one mental skill in one question.</p>	Intended to support understanding of current knowledge, memory, attention, and decision-making processes that can influence behaviour.
	Social Opportunity <ul style="list-style-type: none"> Can you describe any social norms or expectations that impact [performing specific behaviour]? Are there any social support systems or networks that could help you [perform specific behaviour] more effectively? 	Intended to support understanding of social influences, norms, and social pressures that can influence behaviour.
	Physical Opportunity <ul style="list-style-type: none"> Are there any physical barriers or constraints in your environment that impact [performing specific behaviour]?? To what extent do resources such as time, money, and accessibility of health services facilitate/ hinder [performing specific behaviour]?? 	Intended to support understanding of the availability and accessibility of resources, such as time and money, that can influence behaviour.
	Reflective Motivation <ul style="list-style-type: none"> How do you perceive the consequences of [performing specific behaviour]? Can you describe any beliefs or attitudes that influence your decision-making regarding [performing specific behaviour]? Do you intend to change your behaviour? Are you optimistic about changing your behaviour? Do you have specific goals for changing your behaviour? To what extent is this behaviour accepted by your society (friends, family, employment)? 	Intended to support understanding of beliefs about capability, consequences, intention to perform behaviour, goals, optimism, and identity that can influence behaviour.
	Automatic Motivation <ul style="list-style-type: none"> What are your current habits and routines related to the [behaviour]? To what extent will [performing specific behaviour] make you happy or feel? 	Intended to support understanding of emotions, habits, and reinforcement factors that can influence behaviour.

(continued)

Table 2. (continued)

	<ul style="list-style-type: none"> • Are there any incentives or rewards that can motivate you to perform [specific behaviour]? 	
	<p>Additional Questions:</p> <ul style="list-style-type: none"> • What are your expectations from the potential mobile application? • What are the most important things the diabetes application should contain to improve dietary adherence? 	Intended to support understanding of user expectations from technology

3.3 Analyzing Data Gathered with Enriched Topic Guide

The qualitative data needs to be interpreted using a deductive framework approach [48], in which themes and sub-themes are structured within the theoretical framework. Overall, the analysis needs to be divided into three stages, as shown in Fig. 2.

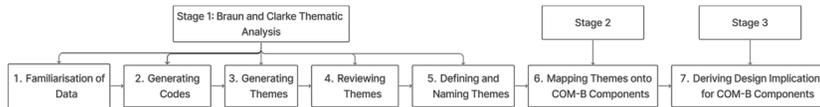


Fig. 2. Proposed Methodological Process for Data Analysis.

In the first stage of data analysis, thematic analysis using five Braun and Clarke’s [49] approach needs to be conducted. Several themes and sub-themes indicating various determinants of behaviour will be identified. Firstly, the data has to be familiarised with double-reading transcriptions and noting initial ideas in the data set (Familiarisation with data). Secondly, initial codes need to be generated across the entire data set (Generating code). Thirdly, themes need to be generated concerning the codes created before for the entire data set (Generating themes). Fourth, themes must be reviewed against the data again, and improvements need to be made if needed (Reviewing themes). Lastly, each theme needs to be defined and named (Defining and naming themes). The process also included selecting data items to use as conversation extracts.

In the second stage, themes need to be mapped onto COM-B components using the framework approach [48]. It will help to organise themes according to COM-B components. For example, forgetting to take medications can be linked with psychological capability.

In the third stage, design implications need to be derived for each thematic category that emerged under the COM-B component. Design implications are the insights or considerations derived from research findings and can guide the development or improvement of a product. These implications suggest how design decisions should be made to address identified needs, challenges, or opportunities. These design implications are refined in subsequent phases of the design, such as user persona and eliciting user requirements.

4 Evaluation of Topic Guide Template: Case Study

It is important to note that the theory-enriched topic study template was designed by experts in Interaction Design and Intervention Design who have knowledge of both Interaction and Intervention Design practices. It was important to evaluate the proposed topic guide template's effectiveness in generating data that could potentially be helpful for designing DBCIs for health and to what extent it could be easily adaptable. The pilot study was conducted by an expert in the field of interaction design who had already been introduced to the COM-B model.

For this purpose, we have conducted a pilot study to understand age-related differences in the management of diabetes of smaller children (7–11) and adolescents (11–18 years of age) and various determinants that influence children's behaviours towards adherence to treatment regimes. Children with Type I Diabetes (T1DM) have to follow complex treatment recommendations, such as physical activity, carbohydrate calculation, and insulin intake. Studies indicate that adherence to treatment recommendations declines significantly during the transition from parental care to self-care and puberty periods, which could be due to the different psychological needs of the children [50, 51].

Six focus groups were conducted with parents of children diagnosed with T1DM and general physicians. Table 3 includes adapted COM-B questions for parents and general physicians. Questions in the proposed topic guide template were carefully adapted to avoid missing any sub-components of the COM-B model and related TDF domains while making it more contextualised to understand the needs of children with T1DM. Various probing questions were also included to understand children's needs in more detail.

Each focus group had 3–6 participants. The focus groups were recorded and transcribed using Sonix's online transcription service (<https://sonix.ai/>), resulting in textual data. The authors reviewed and checked the transcriptions, and corrections were made. The qualitative data was analysed according to the guide provided in Sect. 4.1. The results of the thematic analysis are presented in the following sections.

Table 3. Adapted Theory-Based Topic Guide for Conducting User Research.

COM B Components	Description
 <p>Capability</p>	<ul style="list-style-type: none"> • Physical capability: <i>What difference exists in the physical abilities (physical strength, stamina) of children of various age groups regarding following treatment regimes?</i> • Psychological capability: <i>What is the difference in children's knowledge, mental skills, and mental strength (e.g., develop resilience against temptation/urges, memory, decision-making plan) of various age groups to follow treatment regimens at different ages?</i> <p>Several sub-questions focused on one psychological capability in one question (as mentioned in Table 2).</p>
 <p>Opportunity</p>	<ul style="list-style-type: none"> • Social opportunity: <i>To what extent do social influences (social pressures, norms, etc., from parents, teachers, and kids) facilitate/ hinder adherence? Has gender any role in social influences?</i> (Probe: social influences, norms, social pressures) • Physical opportunity: <i>To what extent do such resources as time, money, and accessibility of health services facilitate/ hinder adherence?</i> (Probe: Availability and accessibility of resources, e.g., time and money) <p>Several sub-questions were made focusing on exploring one domain, such as time, in one question (as mentioned in Table 2)</p>
 <p>Motivation</p>	<ul style="list-style-type: none"> • Reflective motivation: <i>What difference exists in perceived consequences of non-adherence in children of various age groups? What is the difference in children's beliefs and attitudes towards diabetes management at different ages? What is the difference in children's intention to perform diabetes management-related skills at different ages?</i> (Probe: Belief about capability, consequences, intention to perform behaviour, goals, optimism, identity) • Automatic motivation: <i>To what extent do children feel happy, and what motivates them to follow treatment guidelines?</i> (Probe: emotions, habits, reinforcement) <p>Several sub-questions were made focusing on exploring one domain in one question (as mentioned in Table 2)</p>
<p>Additional Questions</p>	<ul style="list-style-type: none"> • What are your expectations from the potential mobile application? • What are the most important things the diabetes application should contain to improve dietary adherence?

4.1 Themes, Sub-themes and Design Implications Related to Capability

The results related to physical capability (individual's physical skills and abilities to perform a behaviour) indicated that children's diabetes-related skills, such as using the pump, calculating carbohydrates, and measuring glycemic levels, improve with age and independence improve with age (Fig. 3). As mentioned by one of the parent's participants: – "He became more independent at about the age of five by operating his pump, and let us say he could operate it himself at six." Similarly, another participant mentioned improvement in skills: – "He has become independent with the pump, with everything, even measuring from the tip of the finger; it comes out better and better with age."

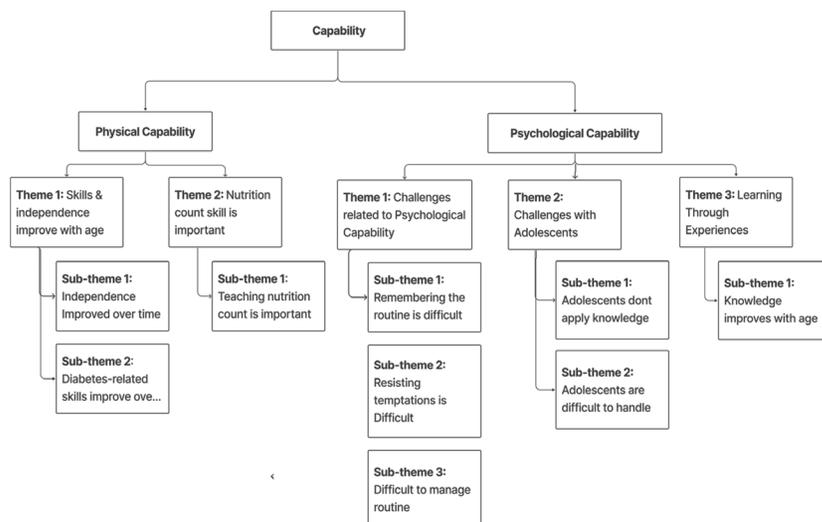


Fig. 3. Themes, Sub-themes and Design Implications Related to Capability.

Children start to show independence at a young age (e.g. wanting to check sugar and inject on their own), but their treatment adherence at a young age is more dependent on their parents. Teaching nutrition counts is important for children, as highlighted by the participant: – “Nutrition teaching is definitely needed.”

Results indicated (Fig. 3) various needs of children with T1DM and age-related differences in children and adolescents related to psychological capability (cognitive resources, knowledge, and understanding necessary to perform a behaviour). Parents and medical staff highlighted issues related to remembering and forgetfulness of tasks needed for disease management (e.g., injecting insulin), specifically in adolescents, as highlighted by participants: – “forgets that he has to do it every time.” The results suggested that children face difficulty resisting temptations.

The current study has highlighted that adolescents are difficult to handle and do not apply knowledge to practice, as indicated by the participant: – “And, this is the time to get out of parental control. That this is actually a very difficult time for the family.” Another participant mentioned: – “At the age of adolescence, their theoretical knowledge can be very good, but then questions arise in practice, just do not apply this knowledge.” This highlights the age-related differences in the psychological capability of children and adolescents.

Based on the results, various design implications for designers can be derived to enhance physical capability and psychological capability in children with T1DM, such as consideration of age-related differences in skills and independence for diabetes management, interactive simulations or boards to help children learn and gain experience, virtual peer mentorship, game features to enhance knowledge and nutrition counting skills, reminders to manage routine, real-time monitoring of behaviour and just-in-time intervention, and features to support goal setting and provide age-appropriate feedback.

4.2 Themes, Sub-themes and Design Implications Related to Opportunity

Various themes related to physical opportunity (external influences and social norms that facilitate or hinder behaviour) have emerged from the collected data, as shown in Fig. 4. For example, changes in schedule, especially during weekends, influence treatment adherence, as indicated by the participant: – “At the weekend, yes, the rhythm goes out of place again; he sleeps longer, and then there are more outdoor activities and other things.” Participants also mentioned issues related to having limited time. No age-related differences were found for physical opportunity.

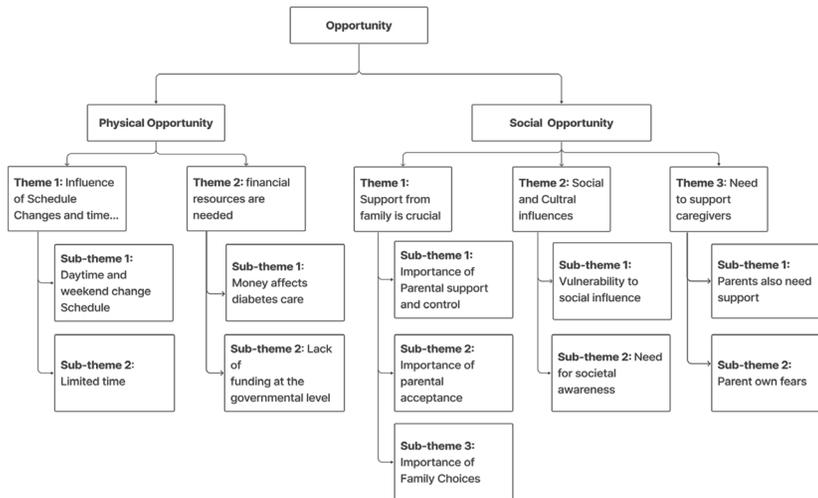


Fig. 4. Themes, Sub-Themes and Design Implications Related to Opportunity.

Various themes related to social opportunity (environmental factors and resources that enable behaviour enactment) have emerged, as shown in Fig. 4. Results have highlighted the importance of family support and parental acceptance in managing diabetes, as reported by the participant: – “A child of any age is a child; in fact, a small person in particular needs parental help. But you can’t say that these bigger teens need it when they say they’re independent, but you need control”. Results indicated that social pressure also influences overall treatment adherence.

Based on the results, various design implications for designers can be derived to maximise physical and psychological opportunities for children with T1DM, such as flexible reminders and alerts to allow adjustments on weekends, provision of developing emergency plans in case unexpected schedule changes Specific weekend plan tools, just-in-time support in high-risk situations, a digital co-communication platform for children and parents, a shared calendar and task tracker, family goal-setting Tools to set diabetes management goals together, and digital tools for tracking parents’ emotions (e.g., stress) and delivering personalised support to parents.

4.3 Themes, Sub-Themes and Design Implications Related to Motivation

The results indicated the difference in reflective motivation (conscious intentions, goals, and beliefs about abilities and consequences) in young children and adolescents (Fig. 5). Findings suggest that children are conscious but do not perceive future consequences and severity of the disease, as mentioned by the participant: – “He does not think that he feels bad after an hour.” However, adolescents know the consequences of the disease but do not intend to follow guidelines: – “Sometimes, pre-teens, teenagers, when they don’t want to do anything...” The results indicated that maintaining motivation is challenging in the long term.

Findings related to automatic motivation (emotions, habits, and routines) indicated in Fig. 5 suggest that children experience many negative emotions mentioned by parents: – “Life with Diabetes is a great stress for her. Because these are tears, disappointments, rejection, and resentment.” Children also experience fear and feelings of fatigue, as highlighted by the participants: – “Sometimes there is the fear of coping and also the fact that one does not dare to admit it all...”

Results also indicated different factors influencing children’s motivation. For example, rewards and incentives, medical reports and visiting doctors: – “When they come for a visit ...many are inspired by the fact that if they have had this bad figure, it has gotten better now that it really motivates or who keep their reading as permanent as well, optimal.”

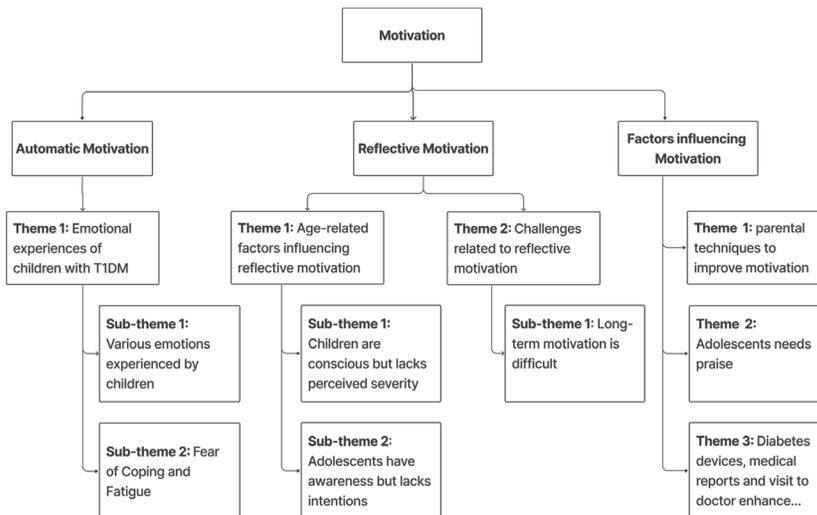


Fig. 5. Themes, Sub-Themes and Design Implications Related to Motivation.

Various design implications for designers were derived to enhance reflective and automatic motivation in children with T1DM, such as age-appropriate design, game features (taking care of an avatar with T1DM and informing of the consequences if it falls ill), features that can support intention formation for adolescents (In-app goal setting,

visualising goals achieved, and in-app incentives or rewards), real-time monitoring of children motivation and emotions and just in time support, online support groups, persuasive messages, features to support online consultation with medical professionals, advanced chatbots or conversational agents, and features like point scoring.

4.4 Summary of Age-Related Differences Among Small Children and Adolescents

Designers need to consider age-related differences and needs when designing DBCIs for health to help children achieve their behavioural goals. Figure 6 presents a brief overview of these differences in the form of a timeline that designers can consider when designing DBCIs for children diagnosed with T1DM to promote treatment adherence.

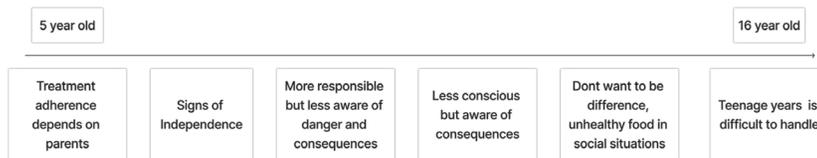


Fig. 6. Age-related Difference in Adherence to Diabetes Management.

Age-related differences highlight the importance of tailored and personalised support for parents, children, and adolescents according to their needs. By considering these differences, more effective and inclusive solutions can be designed and developed to meet the diverse needs of children and adolescents with T1DM.

4.5 Additional Significant Findings

Some suggestions for design emerged directly from parents and medical professionals. For example, parents preferred to use digital mode over paper formats to record data and expressed the need to save data by date. They expressed the need to access children’s health-related data to have control and notifications to observe their children. Medical professionals suggested having an app that can make carb calculation easy (e.g., can capture the image and inform about carbs), supports communication, helps organise meetings, and provides education through mobile applications about the factors that can influence diabetes.

5 Conclusion

The current study explored the provision of an enriching topic guide for interaction design user research methods (focus groups and interviews) with behaviour change theory. We proposed a generic theory-based topic guide template for interaction designers that can help them understand the users’ behaviour change-related needs. The proposed theory-based topic guide aimed to help interaction designers integrate behaviour change theory from the beginning of the design process and provided a structured approach for deriving

design implications aligned with understanding user behaviour change-specific needs. It is important to note that although insights from intervention design research could be valuable for interaction designers, it is still important for them to understand the theoretical components of behaviour change theories and derive design implications aligned with user behaviour change-related needs. The generic topic guide aims to help designers use behaviour change theory while designing DBCIs for health.

The evaluation indicated that the proposed theory-based topic guide template was easy to adapt according to target behaviour (treatment adherence), and it was possible to tailor questions to address parents and medical professionals without losing the theoretical foundations. The result indicated that the theoretical basis of the proposed topic guide template ensured in-depth data collection, providing insights into user needs and clear design implications. The results provided a structured (aligned with theoretical components of the COM-B model) and holistic understanding of the behaviour change-related needs and age-related differences of children with T1DM, which was otherwise not possible using a non-theory-based topic guide.

Several design implications related to improving the capability of children with T1DM were elicited, such as consideration of age-related differences in children's levels of independence and skills, interactive simulations or games to enhance children's skills and independence. The results indicated challenges in managing routines (especially on weekends), peer influences and the importance of parental support. Many design implications can be used to maximise children's opportunities to engage in adherence-related activities. The results indicated different motivational factors, such as visiting the doctor and parental support, that could be supported by the integration of various design features, for example, online consultations and shared calendars with parents to enhance children's motivation to perform adherence-related behaviours. Adolescents need more support in intention formation than smaller children and lack the motivation to engage in diabetes management-related behaviour.

Overall, the results indicate differences in perceived consequences, the severity of the diseases, cognitive abilities, levels of independence and skills among children and adolescents. This means that the design of DBCIs needs to be tailored according to these differences. Hence, a one-size-fits-all approach for designing DBCIs is not appropriate considering these differences. The design implications derived for each thematic category can be theoretically linked with the resulting behaviour change techniques [45], such as reminders and notifications related to prompts and cues. Notably, these design implications can be directly linked with the theory-based determinants of behaviour, which were not likely to be identified using non-theory-based topic guides. Similarly, tracking behaviours is related to feedback and monitoring-related techniques. These design implications can be refined using the taxonomy of behaviour change techniques. For example, the taxonomy lists many types of goal-setting techniques, such as goal setting (behaviour), problem-solving, goal setting (outcome), behavioural contract and commitment, that can be selected.

The proposed generic topic guide template's adaptability and theoretical base would allow the integration of theory from the beginning of the interaction design process. This generic topic guide can be easily contextualised to explore specific problems. Although using the proposed topic guide template would still require a basic understanding of

COM-B components, it will reduce designers' time in extensively reviewing the literature on behaviour change theories. The COM-B-based topic guide template will ensure comprehensive coverage of various determinants of behaviours, enabling designers to gather targeted insights about users and further select appropriate behaviour change techniques. The results can be used in further design phases, such as user personas and generating user requirements for designing DBCIs.

Future studies can adapt the proposed theory-based topic guide template for designing DBCIs and highlight the benefits and limitations of integration of theory interaction design user research.

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References

1. Hekler, E.B., et al.: Advancing models and theories for digital behavior change interventions. *Am. J. Prev. Med.* **51**, 825–832 (2016). <https://doi.org/10.1016/J.AMEPRE.2016.06.013>
2. Yardley, L., Choudhury, T., Patrick, K., Michie, S.: Current issues and future directions for research into digital behavior change interventions. *Am. J. Prev. Med.* **51**, 814–815 (2016). <https://doi.org/10.1016/j.amepre.2016.07.019>
3. Oinas-Kukkonen, H., Win, K.T., Chatterjee, S.: Introduction to health behavior change support systems (HBCSS) minitrack. In: Proceedings of the Annual Hawaii International Conference on System Sciences. 2016-March, vol. 3073 (2016). <https://doi.org/10.1109/HICSS.2016.386>
4. Cooper, A., Reimann, R., Cronin, D., Noessel, C., Csizmadi, J., Lemoine, D.: *About Face The Essentials of Interaction Design*, 4th edn. John Wiley & Sons, Inc., Hoboken (2014)
5. Skivington, K., et al.: A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ* **374** (2021). <https://doi.org/10.1136/BMJ.N2061>
6. Michie, S., West, R., Campbell, R., Brown, J., Gainforth, H.: *ABC of Behaviour Change theories*. Silverback Publishing, Sutton (2014)
7. Michie, S., Atkins, L., West, R.: *The Behaviour Change Wheel: A Guide to Designing Interventions*. Silverback Publishing, Sutton (2014)
8. Hekler, E.B., Klasnja, P., Froehlich, J.E., Buman, M.P.: Mind the theoretical gap: interpreting, using, and developing behavioral theory in HCI research. Presented at the (2013)
9. Yardley, L., et al.: Understanding and promoting effective engagement with digital behavior change interventions. *Am. J. Prev. Med.* **51**, 833–842 (2016). <https://doi.org/10.1016/J.AMEPRE.2016.06.015>
10. Sucala, M., et al.: Behavior science in the evolving world of digital health: considerations on anticipated opportunities and challenges. *Transl Behav Med.* **11**, 495–503 (2021). <https://doi.org/10.1093/TBM/IBAA034>
11. Walsh, J.C., Groarke, J.M.: Integrating behavioral science with mobile (mhealth) technology to optimize health behavior change interventions. *Eur. Psychol.* **24**, 38–48 (2019). <https://doi.org/10.1027/1016-9040/A000351>
12. Jones, M., Marsden, G.: *Mobile Interaction Design*. John Wiley & Sons, Inc., Hoboken (2006)
13. Sharp, H., Rogers, Y., Preece, J.: *Interaction Design: Beyond Human-Computer Interaction*. John Wiley & Sons, Inc., Hoboken (2019)

14. Wei, C., Xing, F.: The comparison of user-centered design and goal-directed design. In: 2010 IEEE 11th International Conference on Computer-Aided Industrial Design and Conceptual Design, CAID and CD'2010, vol. 1, pp. 359–360 (2010). <https://doi.org/10.1109/CAIDCD.2010.5681336>
15. Williams, A.: User-centered design, activity-centered design, and goal-directed design: a review of three methods for designing web applications. In: SIGDOC'09 - Proceedings of the 27th ACM International Conference on Design of Communication, pp. 1–8 (2009). <https://doi.org/10.1145/1621995.1621997>
16. Stewart, D.W., Shamdasani, P.N., Rook, D.W.: Focus Groups: Theory and Practice, 2nd edn. Sage Publications, Inc., Thousands Oaks (2007). <https://doi.org/10.4135/9781412991841>
17. Blake, H., Roberts, A., Stanulewicz, N.: Telemedicine and mHealth interventions for children and young people with type one diabetes (T1DM). *J Endocrinol Diab. Res.* **1**, 100104 (2015)
18. Kwon, B.C., Hur, I., Yi, J.S.: A review of web-based dietary interventions: from the human–computer interaction practitioners' perspective. *Hum. Fact. Ergon. Manuf. Serv. Ind.* **24**, 241–261 (2014). <https://doi.org/10.1002/HFM.20371>
19. Farhat-Ul-Ain, T.V.: Mapping design frameworks for digital behaviour change interventions to goal-directed design. In: 2023 10th International Conference on Behavioural and Social Computing (BESC), pp. 1–7 (2023). <https://doi.org/10.1109/BESC59560.2023.10386260>
20. Krueger, R.A., Casey, M.A.: Focus groups: a practical guide for applied research (2014)
21. Roberts, R.E.: Qualitative interview questions: guidance for novice researchers. *Qual. Rep.* **25**, 3185–3203 (2020). <https://doi.org/10.46743/2160-3715/2020.4640>
22. Sanders, E.B.N., Stappers, P.J.: Probes, toolkits and prototypes: three approaches to making in codesigning. *CoDesign* **10**, 5–14 (2014). <https://doi.org/10.1080/15710882.2014.888183>
23. Vincenzo, J.L., Patton, S.K., Lefler, L.L., McElfish, P.A., Wei, J., Curran, G.M.: A qualitative study of older adults' facilitators, barriers, and cues to action to engage in falls prevention using health belief model constructs. *Arch. Gerontol. Geriatr.* **99**, 104610 (2022). <https://doi.org/10.1016/J.ARCHGER.2021.104610>
24. Nasution, A., Yusuf, A., Keng, S.L., Rasudin, N.S., Iskandar, Y.H.P., Ab Hadi, I.S.: Development of mobile app for breast examination awareness using health belief model: a qualitative study. *Asian Pac J Cancer Prev.* **22**, 3151 (2021). <https://doi.org/10.31557/APJCP.2021.22.10.3151>
25. Atkins, L., et al.: A guide to using the theoretical domains framework of behaviour change to investigate implementation problems. *Implement. Sci.* **12**, 1–18 (2017). <https://doi.org/10.1186/s13012-017-0605-9>
26. Voorheis, P., Bhuiya, A.R., Kuluski, K., Pham, Q., Petch, J.: Making sense of theories, models, and frameworks in digital health behavior change design: qualitative descriptive study. *J. Med. Internet Res.* **25**, e45095 (2023). <https://doi.org/10.2196/45095>
27. Rivera, J., et al.: User-centered design of a mobile app for weight and health management in adolescents with complex health needs: qualitative study. *JMIR Form Res.* **2**, e7 (2018). <https://doi.org/10.2196/formative.8248>
28. Dening, J., George, E.S., Ball, K., Islam, S.M.S.: User-centered development of a digitally-delivered dietary intervention for adults with type 2 diabetes: the T2Diet study. *Internet Interv.* **28**, 100505 (2022). <https://doi.org/10.1016/J.INVENT.2022.100505>
29. Duan, H., et al.: Using goal-directed design to create a mobile health app to improve patient compliance with hypertension self-management: Development and deployment. *JMIR Mhealth Uhealth* **8**, e14466 (2020). <https://doi.org/10.2196/14466>
30. Zhang, Y., Li, X., Luo, S., Liu, C., Liu, F., Zhou, Z.: Exploration of users' perspectives and needs and design of a type 1 diabetes management mobile app: mixed-methods study. *JMIR Mhealth Uhealth* **6**, e11400 (2018). <https://doi.org/10.2196/11400>

31. van Beurden, S.B., Simmons, S.I., Tang, J.C.H., Mewse, A.J., Abraham, C., Greaves, C.J.: Informing the development of online weight management interventions: a qualitative investigation of primary care patient perceptions. *BMC Obes.* **5**, 1–10 (2018). <https://doi.org/10.1186/s40608-018-0184-6>
32. Weerasekara, M., Smedberg, Å.B.: Exploration of user needs and design requirements of a digital stress management intervention for software employees in Sri Lanka: a qualitative study. *BMC Public Health* **23**, 1–13 (2023). <https://doi.org/10.1186/s12889-023-15480-7>
33. Huang, Y., Benford, S., Price, D., Patel, R., Li, B., Ivanov, A., Blake, H.: Using internet of things to reduce office workers' sedentary behavior: intervention development applying the behavior change wheel and human-centered design approach. *JMIR Mhealth Uhealth*. **8** (2020). <https://doi.org/10.2196/17914>
34. Curtis, K.E., Lahiri, S., Brown, K.E.: Targeting parents for childhood weight management: development of a theory-driven and user-centered healthy eating app. *JMIR Mhealth Uhealth* **3**, e69 (2015). <https://doi.org/10.2196/mhealth.3857>
35. Schnell, R., et al.: Theoretically guided iterative design of the Sense2Quit app for tobacco cessation in persons living with HIV. *Int. J. Environ. Res. Public Health* **20**, 4219 (2023). <https://doi.org/10.3390/IJERPH20054219/S1>
36. Dack, C., et al.: A digital self-management intervention for adults with type 2 diabetes: combining theory, data and participatory design to develop HeLP-Diabetes. *Internet Interv.* **17**, 100241 (2019). <https://doi.org/10.1016/J.INVENT.2019.100241>
37. Jones, S.E., Hamilton, S., Bell, R., Araújo-Soares, V., White, M.: Acceptability of a cessation intervention for pregnant smokers: a qualitative study guided by Normalization Process Theory. *BMC Public Health* **20**, 1 (2020). <https://doi.org/10.1186/s12889-020-09608-2>
38. Ajzen, I.: The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* **50**, 179–211 (1991). [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
39. Prochaska, J.O., DiClemente, C.C.: Stages and processes of self-change of smoking: toward an integrative model of change. *J. Consult. Clin. Psychol.* **51**, 390–395 (1983). <https://doi.org/10.1037/0022-006X.51.3.390>
40. Weinstein, N.D., Sandman, P.M., Blalock, S.J.: The precaution adoption process model. *Wiley Encycl. Health Psychol.*, 495–506 (2020). <https://doi.org/10.1002/9781119057840.CH100>
41. Konstanti, C., Karapanos, E., Markopoulos, P.: The behavior change design cards: a design support tool for theoretically-grounded design of behavior change technologies. *Int. J. Hum. Comput. Interact.* **38**, 1238–1254 (2022). <https://doi.org/10.1080/10447318.2021.1990519>
42. Michie, S., van Stralen, M.M., West, R.: The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement. Sci.* **6**, 1–12 (2011). <https://doi.org/10.1186/1748-5908-6-42>
43. McDonagh, L.K., et al.: Application of the COM-B model to barriers and facilitators to chlamydia testing in general practice for young people and primary care practitioners: a systematic review. *Implement. Sci.* **13**, 1–19 (2018). <https://doi.org/10.1186/s13012-018-0821-y>
44. Cane, J., O'Connor, D., Michie, S.: Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implement Sci.* **7** (2012). <https://doi.org/10.1186/1748-5908-7-37>
45. Michie, S., et al.: The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann. Behav. Med.* **46**, 81–95 (2013). <https://doi.org/10.1007/S12160-013-9486-6>
46. Kallio, H., Pietilä, A.M., Johnson, M., Kangasniemi, M.: Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *J. Adv. Nurs.* **72**, 2954–2965 (2016). <https://doi.org/10.1111/JAN.13031>

47. French, S.D., et al.: Developing theory-informed behaviour change interventions to implement evidence into practice: a systematic approach using the Theoretical Domains Framework. *Implement. Sci.* **7**, 38 (2012). <https://doi.org/10.1186/1748-5908-7-38>
48. Gale, N.K., Heath, G., Cameron, E., Rashid, S., Redwood, S.: Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med. Res. Methodol.* **13**, 1–8 (2013). <https://doi.org/10.1186/1471-2288-13-117/PEER-REVIEW>
49. Braun, V., Clarke, V.: Using thematic analysis in psychology. *Qual. Res. Psychol.* **3**, 77–101 (2006). <https://doi.org/10.1191/1478088706QP063OA>
50. Gandhi, K., Vu, B.-M.K., Eshtehardi, S.S., Wasserman, R.M., Hilliard, M.E.: Adherence in adolescents with Type 1 diabetes: strategies and considerations for assessment in research and practice. *Diab. Manag.* **5**, 485–498 (2015). <https://doi.org/10.2217/dmt.15.41>
51. Lyons, S.K., Libman, I.M., Sperling, M.A.: Diabetes in the adolescent: transitional issues. *J. Clin. Endocrinol. Metab.* **98**, 4639–4645 (2013). <https://doi.org/10.1210/jc.2013-2890>

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Behaviour Models-Enriched User Personas for Digital Behaviour Change Interventions

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ABSTRACT

User Persona is a structured *Interaction Design* method for representing a group of users as conceptual models in text and pictorial formats. The regular user Persona descriptions are limited for designing Digital Behaviour Change Interventions for Health. First, they lack the specification of behaviour change goals and target behaviours needed to design behaviour change Interventions. Second, the regular user Personas are mostly static, and they represent only the user's current state and do not address the users' dynamic, long-term behavioural change needs. Third, the user Persona does not help estimate the possible behavioural patterns of the users in the specific context of behaviour change, considering various determinants that influence the users' behaviour. The current work proposes enriching the regular user Persona descriptions with the behaviour change theory. The COM-B Model (Capability, Opportunity, Motivation - Behaviour) and Transtheoretical Model of Change were chosen to enrich user Persona descriptions with behaviour change theory. The current study included the first expert-based evaluation of the theory-enriched Persona description with an Interaction Design expert. The usefulness and overall approach of the enriching Persona descriptions were positively assessed, and future work on making the approach more explicit and precise is recommended.

CCS CONCEPTS

• Human-centred computing; • Interaction design process and methods;

KEYWORDS

Interaction design, User persona, Behaviour change theories, Digital behaviour change interventions

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1 PROBLEM STATEMENT

The use of Digital Behaviour Change Interventions (DBCIs) for Health helps to form new health-promoting behaviours (exercises, healthy eating), altering the current health-compromising behaviours (sedentary behaviour, smoking) and maintaining the newly learned health habits [22]. Designing DBCIs for Health is challenging as it requires knowledge of behaviour change theories and Interaction Design. Behaviour change theories help identify various determinants influencing behaviours (e.g., beliefs, motivation, self-efficacy) and the selection of appropriate behaviour change techniques [9, 11, 20]. The field of Interaction Design primarily addresses designing the interactive behaviour of digital products and developing meaningful relationships between users and digital products. Interaction designers are focused on understanding how users are expected to interact with the digital product and translating their findings into the design of digital products [4, 18]. The frameworks for designing DBCIs for Health suggest designing theory-guided interventions [13, 21]. However, currently, interaction designers do not have a specific approach for combining insights from behaviour change theory with Interaction Design methods such as user Persona and scenarios.

User Persona is a structured Interaction Design method for representing a group of users as conceptual models in text and pictorial formats [2, 4, 14]. User Personas are the archetypical representations of the targeted users and are intended for continuous use throughout the design process of the digital product. User Personas represent the behavioural patterns, goals, expectations, experiences, and anticipated behaviour in a fictional description of a single individual [7]. User Personas can be regarded as accentuated profiles that outline a particular category of users using pertinent criteria sourced from segmentation research, encompassing needs, behaviours, attitudes, and demographics. Cooper et al. [4] proposed defining separate segments in *template and description* for the user Personas to differentiate user groups based on demographic variables and job roles. Users' segmentation has roots in marketing and supports the sales process oriented to different groups of consumers. Segments in user Persona are frequently prioritized by people's engagement in specific activities, age and gender attributes (For example, young females), particular behaviours (For example, working overtime), and occupations within a certain user role (For

example, a freelancer working in the field of information technology) [19]. For designing products that address DBCIs for Health, the regular description for user Personas misses a few important concepts, which are mentioned below:

- In the case of design for behaviour change, defining specific behaviour change goals could contribute to better product design. However, the regular description of Persona does not focus on defining specific behaviour change goals. Behaviour change goals would be useful if the Persona's descriptions could be enriched with data relevant to the behaviour change domain of knowledge.
- Behaviour change is a long-term process consisting of different stages. Individuals can be on different stages of behaviour change (interpersonal variation) and progress from one stage to another over time (intrapersonal dynamic changes). Typically, the user Persona is static, and they do not address these interpersonal and intrapersonal dynamic changes. Using behaviour change theories could contribute to that challenge by defining user segments based on individuals' current stages of change. These stages can further be used to represent intrapersonal dynamic variations over time.
- The user Persona does not help estimate the users' possible behavioural patterns in the specific context of behaviour change. It provides a limited understanding of various factors: psychological, social, and environmental determinants that influence the user's behaviour, such as emotions, beliefs, motivation, personality, habits, norms, and other factors. By directing interaction designers to work with the specific determinants, we assume that their products will have better chances to change the behaviour of users.

The limitations of the regular user Persona description mentioned above pose challenges for interaction designers in designing DBCIs. It is difficult to make design-related decisions without understanding the specifics of behaviour change, such as specific behaviour change goals, the user's stages and determinants that influence behaviour change. One of the ways to deal with the challenges is to integrate behaviour change theories and models into existing user Persona descriptions to capture theory-based user segments, goals, needs and behavioural patterns. In the current work, we aimed to propose a methodological approach on enriching the Persona template and description with behaviour change theories. An Interaction Design expert evaluated theory-integrated user Persona descriptions specifically in the context of DBCIs for Health. This work explicitly addresses the interaction designers who may plan to design DBCIs for Health, as they can benefit from the theory-integrated user Persona template and description. The research questions for the current study are:

RQ 1. How to integrate behaviour change models into regular user Persona description?

RQ 2. To what extent theory-enriched user Persona description may be helpful in identifying user segments, goals, needs, and behavioural patterns compared to a regular user Persona?

2 USER PERSONA DESIGN PROCESS

In this section, the existing user Persona design process is described based on an example of the Goal-Directed Design framework. This

framework has the most detailed description of the user Persona design process [4].

Personas are fictional, specific, and precise representations of target users [17]. They are based on demographic and behavioural personal information collected from users, qualitative interviews, and participant observation. A regular user Persona includes a photo portrait, a fictional name, job title and major responsibilities, demographics such as age, education, ethnicity, family status, the goals and tasks they are trying to complete using the product, and a list of users' needs and fears. The user Persona descriptions also include user segments, issues, barriers, and challenges related to technology [4]. Cooper et al. [4] suggested eight steps for designing user Persona.

Once the user research interviews are done, the first step is to *group the interview subjects by role*. These could be based on job roles or descriptions, family roles, attitudes or approaches towards relevant activities, interests, and aptitudes. The second step involves *identifying distinct behaviour variables* of each role, for example, activities that the user performs (frequency and volume), attitude towards the product of interest, aptitudes of the user, motivation to engage in the product usage, and user abilities related to the product of the interest. At this stage, listing all observed behavioural variables is important. The third step involves *mapping subjects to identified behavioural variables*. The result indicates multiple clusters of the user across each behaviour variable. The fourth step involves *identifying significant behaviour patterns* after mapping individuals with behaviour variables. Interviewees with similar behavioural patterns in six or eight different variables would represent a behaviour pattern, which can be grouped to form the basis of user Persona.

The fifth step involves detailing the behaviour (*synthesizing characteristics and defining goals*), for example, activities, motivations, use environments, frustrations and pain points, skills, experiences, and attitudes associated with the behaviours. Assigning a name to the user Persona is also important at this stage, as it would help to remember and visualize the Persona details. The sixth step involves *checking for completeness and redundancy* with the previous mappings, notes, qualitative data, and others. At this stage, each user's persona should vary from the other one in at least one behaviour. This will ensure that the resulting user personas group sufficiently represents diversity and needs according to the real world. The seventh stage involves prioritizing user Persona *designating persona types* by identifying a single user Persona whose needs and goals can easily be met without compromising other Personas. This single-user Persona would be the primary Persona we would focus on while designing the digital product. Other types of user Personas involve secondary Personas and supplemental personas. The eighth step involves *expanding the Persona description of attributes and behaviour*. At this stage, user Persona descriptions are improved in more detail according to characteristics defined in stage five.

The Persona Anna in Table 1 is an example built on a regular Interaction Design Persona template and description. Such user Persona misses the specific concepts relevant to the behaviour change. For example, the goal of learning how to stop working on time is broad in general and does not highlight why the user has this specific goal, what the user needs to achieve it, and the ways how she wants to do that. The segment description is insufficient

Table 1: User Persona Built on Regular Template and Description

	<p>Demographics: NAME: Anna; AGE: 29; GENDER: Female; LOCATION: Riga, Latvia; FAMILY STATUS: Long-term relationship without children; EDUCATION: Master's degree; JOB TITLE: Marketing Specialist; INDUSTRY: IT;</p>
<p>IN SEGMENT: Young female in IT industry</p>	
<p>Quote: "I want to return to my normal life and enjoy time away from work."</p>	
<p>Bio: Anna is a local from Berlin. She serves individuals employed in the IT sector as a freelance marketing specialist and delivers targeted marketing services to IT companies. She has to show a constant online presence to be competitive in the market among other marketing professionals. She wants to grow in her career, but too much work prevents her from enjoying life and spending time with her partner, who has already begun to be distant. Feeling burnt out lately, Anna became concerned about her mental health and realised that the first thing she needed to do was to change her habits and routine.</p>	
<p>Habits & Routines: Anna works more than 8 hours daily by laptop, but she continues from her smartphone when she is not at the desk. She has to show a constant online presence to be competitive in the market among other marketing professionals. She posts actively on social media because she shows examples and ideas of what her clients could do with their social media accounts.</p>	
<p>Dislikes, concerns, fears (-): She spends too much time working and misses her personal life; she doesn't want to become distant from her partner; she is afraid of not having a planned routine and time to do everything in high quality.</p>	
<p>Likes, interests, and desires (+): She wants to be competitive in the market; Anna likes to spend time with her loved ones.</p>	
<p>Motivators: To spend more time with her partner and feel mentally and physically relaxed.</p>	
<p>Goals/Needs: To learn how to stop working on time.</p>	
<p>Challenges & Barriers: She does not have specific technology/tools to help her manage her routine except the laptop and smartphone; she is afraid of not being understood by her clients if she changes her routine and will be unavailable for a while.</p>	
<p>Values: Kindness, integrity, loyalty, hard work, relationships.</p>	
<p>Technology Preferences: Use of laptop and phone daily - she works more than 8 hours daily with a laptop. In her work, as well as in her personal life, Anna mainly uses social media channels: LinkedIn, Instagram, Facebook, and Twitter.</p>	

because the user needs might vary within the same segment (young females in the IT industry). Some users might need more awareness regarding issues of overtime work, while others might have already developed awareness regarding the issue. This is also referred to as the individual stage of change. This means that segments in regular user Persona could be more specified according to the individual current stage of change. Currently, the challenges and barriers do not require highlighting the challenges in the context of behaviour change. For example, what social, psychological and environmental factors are influencing the user behaviour change process, such as peer pressure, lack of motivation or skills needed to perform certain tasks?

Thus, the user Persona built on the basis of a regular Persona description lacks specific information needed for designing DBCIs, such as behavioural goals, stage of change, challenges, and barriers related to behaviour change. Understanding the behaviour change process based on the behaviour change theories [10] can be useful in overcoming these issues. In the following section, we will provide brief overview the behaviour change theories and propose an approach for the integration of behaviour change theories in the user Persona description.

3 PROPOSED APPROACH FOR INTEGRATING BEHAVIOUR CHANGE THEORY

3.1 A Brief Overview of Behaviour Change Theories

An extensive body of literature is available in the field of behaviour change based on more than 83 behaviour change theories [12], which highlight different psychological, social, and environmental determinants that influence the user's behaviour, such as emotions, beliefs, motivation, and other factors. Theories proposed in this field [12] are divided into two broad categories. Theories of behaviour prediction [1, 5, 6] highlight specific determinants of behaviour that influence health-related behaviours. Stage-based theories highlight that different individuals can be on different behaviour change stages, and individual needs can vary as they progress from one stage to another [15]. Below, we have provided a short overview of the practically useful behaviour change model and an approach for enriching user Persona descriptions with them.

Michie et al. [11] proposed a Behaviour Change Wheel (BCW) to guide the step-by-step process for selecting a target user group (young female), identifying behavioural goals and target behaviours for change, and conducting theory-based user research to identify determinants of behaviour based on the COM-B model (Capability, Opportunity, and Motivation-Behaviour). A behaviour change goal is defined as the ultimate target outcome of behaviour change interventions, such as going for physical activity. Identifying target

Table 2: User Persona Built on Theory-Enriched Template and Description



DEMOGRAPHICS: NAME: Anna; AGE: 29; GENDER: Female; LOCATION: Berlin, ; FAMILY STATUS: Long-term relationship without children; EDUCATION: Master’s degree; JOB TITLE: Marketing Specialist; INDUSTRY: IT;

IN SEGMENT: Contemplation stage

Quote: "I want to return to my normal life and enjoy time away from work."

Bio: Anna is a local from Riga. She serves individuals employed in the IT sector as a freelance marketing specialist and delivers targeted marketing services to IT companies. She has to show a constant online presence to be competitive in the market among other marketing professionals. She wants to grow in her career, but having too much work prevents her from enjoying life and spending time with her partner, who has already begun to be distant from her. Feeling burnt out lately, Anna became concerned about her mental health and realised that the first thing she needed to do was to change her habits and routine. *Being a shy person, she doesn't feel comfortable talking to her clients about the existing problem and the need for a change of her work schedule and routine.*

Habits and Routines related to Behaviour Change: Anna works more than 8 hours daily by laptop, but when she is not at the desk, continues from the smartphone. She has to show a constant online presence to be competitive in the market among other marketing professionals. She posts actively on social media because she shows examples and ideas of what her clients could do with their social media accounts. *She mainly uses WhatsApp to communicate with her clients and colleagues. She is always alert and never turns off notifications so she can read all messages immediately.*

Goals related to Behaviour Change: Learn "how to close a laptop and stop working" on time to feel mentally and physically relaxed.

Target behaviour: To develop a habit of stopping working when the work hours end.

Specification of target behaviour: To close all work-related devices and apps, stop working after 6 p.m. and stop thinking about it, mute the WhatsApp notifications, and set up the focus mode.

Dislikes, concerns, fears (-) related to Behaviour Change: Anna spends too much time working and misses her personal life; she doesn't want to become distant from her partner; she is afraid of not having a planned routine and time to do everything in high quality; she feels burnout, and she is afraid of not being understood by her clients if she changes her routine and will be not available for a while.

Likes, interests, desires (+) related to Behaviour Change: She likes to spend time with her beloved ones. Anna would like to have better time management and planning skills. **Motivators:** Anna wants to find the right life-work balance to be productive and effective in work, but get more time for her personal life and take care of her mental health.

COM-B-based Challenges & Barriers Related to Behaviour Change:

Psychological Capability: She needs to increase her ability to plan her schedule and regular resting time.

Social Opportunity: Her clients need to understand her need to be away from work (not being reachable for a while). She feels pressure from other marketing specialists and what they set as social norms.

Physical Opportunity: She does not have specific technology/tools to help her manage her routine except the laptop and smartphone.

Reflective Motivation: She believes that digital marketers should always be present and because of that she thinks she cannot just pause the work and focus on her personal life and quit all work-related applications.

Automatic Motivation: Anna always wants to check social media to respond to every message quickly, and because of that, even if she closes all work-related applications, she automatically/habitually checks them every 5 minutes and cannot relax.

Values: Kindness, integrity, loyalty, hard work, relationships.

Technology Preferences: Use of laptop and phone every day - she works more than 8 hours daily with the laptop. In her work, as well as in her personal life, Anna mainly uses social media channels: LinkedIn, Instagram, Facebook, and Twitter.

behaviours involves enlisting various behaviours that could help us achieve behaviour change goals (scheduling time for physical activity, getting reminders, planning daily routine) and selecting the most appropriate target behaviour (getting reminders) from the list based on goals that could be easy to change, greater spillover effect and measurable. The specification of target behaviour involves what the user needs to do differently to achieve the target behaviour (e.g., setting reminders at 6:00 p.m.). The theory-integrated user

Persona description should include behavioural goals and the target behaviour, allowing interaction designers to design products according to the user’s goals.

Lastly, conducting theory-guided research helps to identify specific determinants influencing behaviours. Michie et al. [9, 11] proposed the COM-B model (Figure 1) by integrating nineteen frameworks of Health behaviour change. It allows researchers to consider a wide range of determinants influencing behaviour rather than selecting a single theory that suggests a few determinants influencing behaviour [8]. Each of these components is further

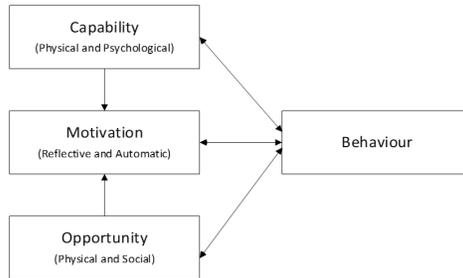


Figure 1: COM-B model [11].

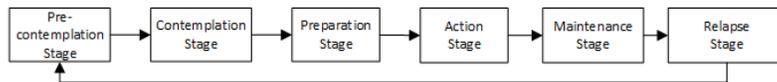


Figure 2: Transtheoretical model of change [16].

divided into two categories. Capability can be categorised as psychological capability and physical capability. Physical capability is the physical skills, strength or stamina needed to perform the behaviour. Psychological capability is knowledge and psychological skills such as behavioural regulation, resilience, and memory required to perform the behaviour. Opportunity can be categorised as a physical opportunity (time, resources, etc.) and social opportunity, such as social norms. Motivation can be categorized as reflective motivation (individual beliefs about capabilities) and automatic motivation (desires, moods, habits). Figure 1 highlights that Capability, Motivation and Opportunity will influence behaviour, and both Capability and Opportunity also influence user Motivation to perform behaviour.

The BCW also proposed the method of linking research-based findings (determinants of behaviour) with the selection of behaviour change techniques; for example, goal setting or prompts and cues can be selected to improve psychological capabilities such as resilience or memory. Michie et al. [10] provided a comprehensive taxonomy of 93 behaviour change techniques. Overall, selecting behavioural goals, target behaviour, and COM-B-based determinants of behaviour are the prerequisites for selecting appropriate behaviour change techniques and designing behaviour change interventions. The COM-B model-guided research and BCW should help designers identify the specific challenges and barriers related to behaviour change, and it can be added to the theory-enriched user Persona description to ensure the right process of creating a Persona. Designers can select appropriate behaviour change techniques from the list and implement them in DBCIs.

Prochaska and DiClemente [16] proposed the *Transtheoretical Model of Change* (stage-based theory), suggesting that behaviour change is a long-term process and consists of six stages (Figure

2): the *pre-contemplation* (not willing to change behaviour), *contemplation* (willing to change behaviour), *preparation* (planning to take action), *action* (taking active actions to change behaviour), *maintenance* (the user maintain the newly learned behaviour over time) and *relapse* (returning to any stage of change).

The Transtheoretical Model of Change allows us to capture and define the current behaviour change stage for user Persona in the form of user segments. For example, individuals in the pre-contemplation and contemplation stages can be reflected in two user segments. The Transtheoretical Model of Change highlights behaviour change as a long-term process, which means that the user Persona should be considered differently according to individual dynamic changes. The classic representation of a user Persona is static (static user Persona) [3]. It is based on initial user research and represents just the current state of the users. However, such representation is insufficient, considering that the potential users stated are constantly changing while the users interact with a product. To avoid such limitations, the concept of dynamic user Personas was proposed [3]. Dynamic Personas are changed and evolved in the same way the actual users do and can be more suitable for products aiming at long-term processes such as DBCIs. The dynamic Persona is a flexible representation of the target audience that considers changes in the audience's characteristics, preferences, and behaviours over time. Behaviour change experts and Interaction designers can assume variations according to the stage of change and pre-select behaviour change interventions. Overall, it is important to integrate the knowledge of behaviour change theories into Persona descriptions for modelling users, specifically for DBCIs.

Table 3: Expert Feedback after Evaluating Theory-Enriched Persona Template and Description

Evaluated Categories	Expert feedback
Overall theory-enriched user Persona description	The expert agreed that the overall approach is useful for designing DBCIs for Health. The expert recalled her previous experience when the team had to develop a new version of the Persona for the specific context (however, that work was not directly linked with the Behaviour Change domain). The expert finds theory-enriched user Persona descriptions useful in this domain of Behaviour Change.
Persona’s Segments based on the phases of the Transtheoretical Model of Change	The expert commented that it would be useful to write a brief description of the stage and make it more understandable for designers, “a text that would be easier (to understand) for designers. For example, “Anna has been preparing for change for six months to develop more understanding about users...” A little bit of a story about the stage she is in”. The expert added that designers need to understand the value of using this theory for defining user segments; as the expert said: “Why the design would be better if they knew this as compared to the traditional Persona... it needs to be easy for the designers... I am a bit concerned if they will understand what you want them to understand”. The expert suggested making the descriptions more explicit and precise by using a short presentation explaining why this is needed.
Using the COM-B model for specifying behaviour goals, target behaviours	The expert mentioned “it’s fair” to add these sections for designing specifically DBCIs for Health. The expert also emphasised explaining the usefulness of these sections and making them more understandable for designers.
Specifying challenges and barriers based on the COM-B model	The expert agreed with the importance of adding challenges and barriers based on the COM-B model and mentioned that “It only talks to them if it is directly useful to them. . . it will talk to them if they are designing tools for psychological capability, etc. . . but if they are not working with these dimensions then it would be probably over the top”. It means that the designers need to have a clear idea about these domains and how these should be used further in designing DBCIs for Health.
Additional suggestions	The expert emphasised making the template more visually appealing for the designers, for example, adding colours or sliders, to make it easy and motivating for designers to use. The expert also emphasised the importance of using Persona throughout the design process and to consider the challenges related to the use of user Persona by experts. The expert suggested making it explicit to use user Persona when designing DBCIs for Health, and maybe checking digital products using user Persona would be very useful.

3.2 ENRICHING USER PERSONA WITH COM-B MODEL AND TRANSTHEORETICAL MODEL OF CHANGE

Our version of the user persona includes the following descriptions and sections based on the COM-B model and the Transtheoretical Model of Change.

1. *Defining user segments based on the Transtheoretical Model of Change:* The theory-integrated user Persona description should define user segments based on the Transtheoretical Model of Change. Users at different stages can be grouped according to their current stage of change. This section should allow the user Persona to map segments according to the users’ dynamic behavioural stages. It will enable designers to define user segments according to the user’s current behaviour change stage and plan interventions.
2. *Defining users’ goals and target behaviours:* The theory-integrated user Persona should define user goals in the context of behaviour change. The additional sections for the target behaviour and specification are added to the regular persona description. This should allow designers to understand the specific behaviour change goals and target behaviours of the individuals.

3. *Defining challenges and barriers based on the COM-Model:*

The theory-integrated user Persona description will describe the user’s challenges and barriers based on the COM-B model (based on the COM-B guided research already conducted to identify determinants of behaviour). It will provide an understanding of various determinants of behaviour based on the COM-B model that influence the user’s behaviour, such as emotions, beliefs, motivation, and other factors. It will allow interaction designers to select behaviour change techniques according to challenges and barriers.

4. *Specifying a quote, bio, likes/dislikes, and goals in the context of Behaviour Change:*

All sections of the user Persona should be specified in the context of behaviour change (quote, bio, like/dislike, habits and routine, challenges and barriers). Thus, the descriptions of the sections should be specifically contextualised for behaviour change needs. The added sections and descriptions with behaviour change determinants based on the COM-B model and the Transtheoretical Model of Change are presented in Table 2 and are marked in *italics*.

By adding theory-based sections and descriptions, we assume that interaction designers can better understand the user’s specific behaviour change needs and goals. The current research aims to help designers make better DBCIs by integrating theories into regular user Persona. We have further evaluated the theory-integrated

user Persona design with an expert in the field of Interaction Design. Following are the details of the evaluation process and results.

4 EVALUATION OF THE USER PERSONA

After integrating the COM-B model and Transtheoretical Model Change into a user Persona example, the next aim was to evaluate theory-enriched user Persona description. One experienced expert in the field of Interaction Design and Persona was selected for the qualitative research study. The expert has extensive expertise in the field, demonstrated through a minimum of thirty years of practical experience in designing methods and guided processes for designers. The expert is proficient in proposing and evaluating methods for designers. A semi-structured interview was conducted with the expert for which an interview protocol was prepared. The interview protocol consisted of two major sections. The context of the current study was explained in the first section, including the challenges in using a regular user Persona description for designing DBCIs. This section also describes the COM-B and Transtheoretical Model of Change so the expert can become familiar with behaviour change theories integrated into the user Persona template and description. In the second section, the example of a regular user Persona and an enhanced theory user Persona were provided (as shown in Table 1 and Table 2). The interview questions were broadly focused on the usefulness of enriched user Persona description with the behaviour change theory for designing DBCIs. The interview took an hour, and the expert shared feedback on the approach and provided valuable suggestions for future work. The results of the expert Interview are presented below (Table 3).

5 CONCLUSION

The current study was focused on enriching user Persona descriptions with the Transtheoretical Model of Change and COM-B model to specify user segments, behaviour change goals, target behaviours, challenges, and barriers specifically in the context of Designing DBCIs for Health. The evaluation of the theory-enriched user Persona indicated that the approach of enriching Persona descriptions with the behaviour change theory could be useful for designers. The expert suggested simplifying the content for designers; for example, providing additional descriptions in the segment section and explaining the COM-B components more precisely via a short presentation for the designers to understand the importance of adding specific theories and sections could be useful. Future studies can focus on conducting workshops with designers and experts working specifically on designing for behaviour change to evaluate how theory-enriched user Personas could help the overall design process of DBCIs for Health behaviour change. This study contributes to the field of Interaction Design by proposing a way to enrich the user Personas for designing DBCIs for Health behaviour change.

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REFERENCES

- [1] Ajzen, I. 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes*. 50, 2 (Dec. 1991), 179–211. DOI:https://doi.org/10.1016/0749-5978(91)90020-T.

- [2] Blomquist, Å. and Arvola, M. 2002. Personas in action: Ethnography in an interaction design team. *ACM International Conference Proceeding Series*. 31, (2002), 197–200. DOI:https://doi.org/10.1145/572020.572044.
- [3] Bonnardel, N. and Pichot, N. 2019. Enhancing collaborative creativity with virtual dynamic personas. (2019).
- [4] Cooper, A., Reimann, R., Cronin, D., Noessel, C., Cszizmadi, J. and Lemoine, D. 2014. *About Face The Essentials of Interaction Design* Fourth Edition.
- [5] Fisher, W.A., Fisher, J.D. and Harman, J. 2009. *The Information-Motivation-Behavioral Skills Model: A General Social Psychological Approach to Understanding and Promoting Health Behavior*. *Social Psychological Foundations of Health and Illness*. (Dec. 2009), 82–106. DOI:https://doi.org/10.1002/9780470753552.CH14.
- [6] Jones, C.L., Jensen, J.D., Scherr, C.L., Brown, N.R., Christy, K. and Weaver, J. 2014. *The Health Belief Model as an Explanatory Framework in Communication Research: Exploring Parallel, Serial, and Moderated Mediation*. *Health Communication*. Routledge.
- [7] LeRouge, C., Ma, J., Sneha, S. and Tolle, K. 2013. User profiles and personas in the design and development of consumer health technologies. *International Journal of Medical Informatics*. 82, 11 (Nov. 2013), e251–e268. DOI:https://doi.org/10.1016/j.ijmedinf.2013.03.006.
- [8] McDonagh, L.K., Saunders, J.M., Cassell, J., Curtis, T., Bastaki, H., Hartney, T. and Rait, G. 2018. Application of the COM-B model to barriers and facilitators to chlamydia testing in general practice for young people and primary care practitioners: A systematic review. *Implementation Science*. 13, 1 (Oct. 2018), 1–19. DOI:https://doi.org/10.1186/s13012-018-0821-y/TABLES4.
- [9] Michie, S., Atkins, L. and West, R. 2014. *The Behaviour Change Wheel: A Guide To Designing Interventions*. undefined. (2014).
- [10] Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M.P., Cane, J. and Wood, C.E. 2013. The behaviour 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 (Aug. 2013), 81–95. DOI:https://doi.org/10.1007/s12160-013-9486-6.
- [11] Michie, S., van Stralen, M.M. and West, R. 2011. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*. 6, 1 (Apr. 2011), 1–12. DOI:https://doi.org/10.1186/1748-5908-6-42/TABLES3.
- [12] Michie, S., West, R., Campbell, R., Brown, J. and Gainforth, H. 2014. ABC of behaviour change theories. (2014), 499.
- [13] Mummah, S.A., Robinson, T.N., King, A.C., Gardner, C.D. and Sutton, S. 2016. IDEAS (integrate, design, assess, and share): A framework and toolkit of strategies for the development of more effective digital interventions to change health behavior. *Journal of Medical Internet Research*. 18, 12 (Dec. 2016). DOI:https://doi.org/10.2196/jmir.5927.
- [14] Nolte, A., Lueneburg, K., Wallach, D.P. and Jochems, N. 2022. *Creating Personas for Signing User Populations: An Ability-Based Approach to User Modelling in HCI*. *ASSETS 2022 - Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*. (Oct. 2022). DOI:https://doi.org/10.1145/3517428.3550364.
- [15] O'gallagher, P. and Adam, F. 2017. Raghallaigh, Adam / Designing Health Interventions *Journal of the Midwest Association for Information Systems*. Available *Journal of the Midwest Association for Information Systems* 1, 2 (2017), 41–56.
- [16] Prochaska, J.O. and DiClemente, C.C. 1983. Stages and processes of self-change of smoking: Toward an integrative model of change. *Journal of Consulting and Clinical Psychology*. 51, 3 (Jun. 1983), 390–395. DOI:https://doi.org/10.1037/0022-006X.51.3.390.
- [17] Pruitt, J.S. and Adlin, T. 2006. *The Persona Lifecycle: Keeping People in Mind Throughout Product Design*. *The Persona Lifecycle: Keeping People in Mind Throughout Product Design*. (Jan. 2006), 1–724. DOI:https://doi.org/10.1016/B978-0-12-566251-2.X5000-X.
- [18] Saffer, D. 2009. *Designing for Interaction: Creating Innovative Applications and Devices* (2nd Edition) (Voices That Matter). (2009), 240.
- [19] Segmentation vs. Personas - What's The Difference? - Relevant Insights: 2021. <https://www.relevantinsights.com/articles/segmentation-vs-personas-what-is-the-difference/>. Accessed: 2023-10-08.
- [20] Skivington, K., Matthews, L., Simpson, S.A., Craig, P., Baird, J., Blazeby, J.M., Boyd, K.A., Craig, N., French, D.P., McIntosh, E., Petticrew, M., Rycroft-Malone, J., White, M. and Moore, L. 2021. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ*. 374, (Sep. 2021). DOI:https://doi.org/10.1136/bmj.n2061.
- [21] Wang, Y., Fadhil, A., Lange, J.P. and Reiterer, H. 2019. Integrating Taxonomies Into Theory-Based Digital Health Interventions for Behavior Change: A Holistic Framework. *JMIR Research Protocols*. 8, 1 (Jan. 2019). DOI:https://doi.org/10.2196/RESPROT.8055.
- [22] Yardley, L., Choudhury, T., Patrick, K. and Michie, S. 2016. Current Issues and Future Directions for Research Into Digital Behavior Change Interventions. *American Journal of Preventive Medicine*. 51, 5 (Nov. 2016), 814–815. DOI:https://doi.org/10.1016/j.amepre.2016.07.019.

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Mapping Behavior Change Wheel Techniques to Digital Behavior Change Interventions: Review

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Abstract. Aims: Digital health interventions (DHIs) use different strategies to deliver behavior change techniques (BCTs). There is a lack of understanding on how BCTs can be strategized in DHIs to optimize users' experience and effectiveness of the intervention. This review aimed to explore how behavior change techniques are strategized/operationalized in DHIs de-facto. **Method:** Thirty-five studies were included in the review. Data related to behavior change strategies were extracted and coded using the taxonomy of behavior change techniques. **Results:** Overall, 125 strategies were extracted from studies and coded into 33 BCTs. Most of the studies were focused on physical activity and healthy food consumption. 'Prompts and cues' (17/35 studies), 'social support (unspecified technique)' (15/35 studies), 'goal setting (behavior technique)' (11/35 studies), and 'self-monitoring of behavior' (10/35 studies) were the most frequently used behavior change techniques. 'Prompts and cues' was mostly strategized by sending reminders via text messages/email, mobile applications, or other digital systems. 'Social support' such as encouragement or counseling was strategized by online support groups using social networking websites, text-message platforms, and counselors' phone calls. 'Goal setting (behavior technique)' was strategized via in-app calculators to set goals, build-in app features, and digital coach/virtual agents. 'Self-monitoring of behavior' was mainly strategized by transferring data in the mobile application (by users) and activity trackers. **Conclusion:** It is important to consider theories/frameworks of behavior change while selecting, strategizing, and reporting BCTs to produce effective and sustainable results. Furthermore, innovative ways of strategizing various BCTs are needed to be implemented in DHI.

Keywords: Digital health interventions · Behavior change · Behavior change techniques

1 Introduction

1.1 Problem Statement

Digital health interventions (DHIs) for behavior change, e.g., smoking cessation, improving adherence, or dietary habits, have been more prominent within the last decade [1]. The goal of digital behavior change interventions (DBCIs) is to achieve sustainable

change in targeted health outcomes and improve user engagement through a positive user experience [2, 3]. Behavior Change Techniques (BCTs) are observable, replicable, and irreducible components of an intervention designed to change behaviors. DHIs are usually complex in terms of BCTs (e.g., use of multiple BCTs) or features of the technology (e.g., interactive features, ease of use, timely accessible information, personalization, privacy). Various methods have been employed in DHIs to deliver specific BCTs. E.g., wearables, smartphones applications, exergaming, and social media were used to deliver self-monitoring techniques for improving physical activity [4].

Moller et al. [5] identified some potential issues about the operationalization of BCTs. First, the studies lack an appropriate description of BCTs in terms of theory and how exactly BCTs were strategized/offered in the interventions [6–8]. For example, studies reported only methods of delivery such as text-message interventions without mentioning the BCTs specifically used. Thus, that challenges to identify, implement, and replicate the active behavior change components. Second, BCTs are strategized inconsistently with the theory. For example, a theoretical construct '*autonomy and support*' derived from self-determination theory can be strategized by giving choices to the participants. However, these choices were given inconsistently with the theory, e.g., giving too many choices or meaningless options. Third, a minimal number of BCTs have been implemented in mobile applications. E.g., less than seven BCTs on average are being implemented in apps for physical activity [9, 10]. This suggests a lack of guidance from the theory in DHI, limiting the efficacy of interventions. Thus, greater precision is needed in the operationalization and specification of BCTs to improve the potential of DHI. However, there is a lack of understanding of how BCTs could and should be strategized in digital technology. The current study aimed to conduct a literature review to understand how BCTs are typically operationalized/strategized in DHI.

1.2 Research Question

What strategies are mostly used in the existing DBCI studies to deliver the specific behavior change techniques in the digital interventions?

1.3 The Behavior Change Wheel

Studies describe active components of behavior change interventions with different labels, e.g., daily record keeping can be used as an alternative to self-monitoring [11]. Further, different frameworks, such as IDEAS [13], suggest incorporating theory into intervention design. The UK Medical Research Council [14] calls for improved methods of specifying and reporting intervention content to address the problems related to lack of consistency and consensus. Recently, Michie et al. [14] developed a behavior change framework known as the Behavior Change Wheel (BCW, see Fig. 1), which aids in the intervention design process and characterizes interventions that enable their outcomes to be linked with mechanisms of action. The behavior change wheel integrates nineteen theories of behavior change and offers a step-by-step process of designing interventions. Stage 1 of BCW (see Fig. 1) helps to understand the problem and identify the need for change based on the Com-B model (inner layer: Capability, Opportunity, and Motivation). The second stage identifies what types of intervention functions (middle layer:

broad categories of means by which an intervention can change behavior) and policy categories (outer layer) are likely to bring the desired change. The last stage is related to identifying the specific behavior change technique with the help of taxonomy of behavior change and how this should be implemented (i.e., strategies/operationalization of BCTs).

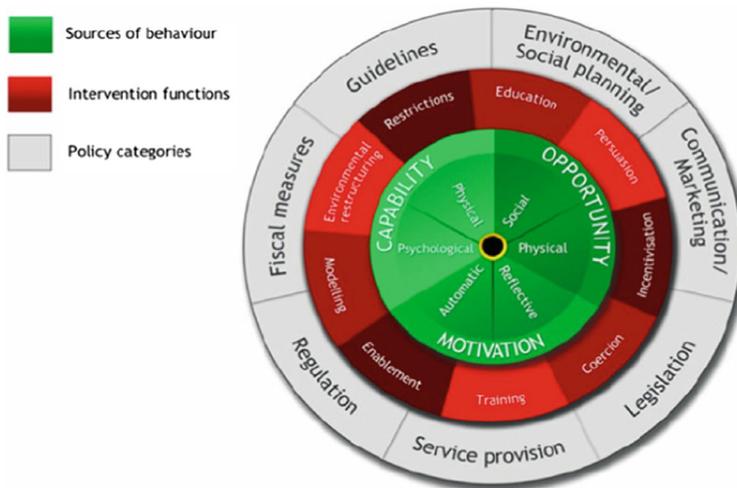


Fig. 1. Behavior Change Wheel (BCW)

The authors created a taxonomy of the behavior change techniques [16], which combined 93 BCTs (grouped into 16 categories) to establish common vocabulary and definitions of behavior change techniques. These BCTs are also categorized as more frequently and less frequently used techniques for each intervention function. This structured approach enabled precision in the intervention design, implementation, and evaluation. The taxonomy of BCTs has several benefits [16]. First, it allows designing intervention by selecting BCTs from a comprehensive list and reporting details as required by the definition of specific BCTs mentioned in the taxonomy. Second, it promotes replication of interventions strategies and labeling strategies by appropriate BCTs. Lastly, it provides reliable methods of extracting intervention strategy/content from studies and accurately labeling them. This study aimed to extract information regarding various strategies used for behavior change and to label them using behavior change taxonomy [16]. This should help in the understanding of various strategies used to deliver specific behavior change techniques.

2 Related Works

In the previous reviews [16–19], researchers evaluated BCTs delivered in commercial applications empirical studies designed for some specific targeted outcomes, e.g., sedentary behavior, alcohol consumption reduction, weight reduction. The authors synthesized

the results to reflect the absence/presence of the BCTs in application or studies. For example, Morrissey et al. [16] coded commercial smartphone applications for improving medication adherence using the Behavior Change Technique Taxonomy (v1). Only 12 out of 93 possible techniques were utilized across apps. Approximately 96% of the apps included *'action planning'* and *'prompts & cues'*. Approximately 37% of studies used *'self-monitoring and feedback on behavior'*. Simeon et al. [17] coded 71 studies that used social media interventions to promote health via behavior change in adults. However, the top 5 BCTs delivered in the maximum intensity were *'social support (unspecified)'*, *'self-monitoring of behavior'*, *'information about health consequences'*, and *'credible sources'* were identified to give instructions on how to perform a behavior. Lyons et al. [18] coded behavior changes techniques implemented in commercially available electronic activity monitors. The most used techniques were *'review of goal behavior'*, *'social support'*, *'social comparison'*, *'prompts/cues'*, *'rewards'*, and *'focus on the past success'*. Dunn et al. [19] reviewed apps that have been designed to reduce the sedentary periods. The results showed that in free and paid apps, the BCTs used were only 10 out of 93, with a mean of 2.42 range (0–6) per app. The most commonly used BCTs were *'prompts/cues'*, *'information about health consequences'*, and *'self-monitoring behavior'* (n = 17). Three additional BCTs, *'graded tasks'*, *'focus on past successes'*, and *'behavior substitution'*, were coded from the four free apps. Schoeppe [20] identified 6 BCTs per app to improve diet, physical activity, and sedentary behaviors in children & adolescents, i.e., *'providing instructions'*, *'general encouragement'*, *'contingent rewards'*, and *'feedback on performance'* were the most commonly used BCTs. These literature reviews highlighted that some techniques are more frequently used in the studies than others in digital interventions.

3 Methods

Electronic databases (ACM, MEDLINE, PubMed) were searched using key terms related to digital technology/digital interventions and health behavior change intervention. Studies were included if: any form of digital technology was included (e.g., mobile applications, websites, text messages, etc.) and focused on at least one health behavior (e.g., reducing alcohol consumption, improving adherence, quality of life, etc.). Only studies from the last fifteen years were included in the current review. All types of studies (experimental, non-experimental, design, and prototype) were included. Information regarding implemented strategies was extracted and coded using the BCW taxonomy for all the included studies. Then, the authors reviewed the included studies and coded strategies.

4 Results

Thirty-five studies were included in the current review. Information related to BCTs, mode of delivery, and targeted conditions were extracted. One hundred twenty-five strategies were extracted from 35 studies and labeled using the Taxonomy of behavior change (V1). All strategies were labeled with the most appropriate BCTs. However, in some cases, an adequate description of the strategy was not mentioned, which was labeled as *'not enough information to code'*. Moreover, some studies utilized interventions that

cannot be coded as BCTs were labeled as ‘*No BCT present*’. The included studies ranged from the year 2013-to 2021.

4.1 Targeted Domains for Health Behavior Change

The examined studies targeted multiple health behaviors for change (see Fig. 2). Most of the studies were focused on physical activity/reduction in sedentary health behaviors (12/35), followed by health food consumption (9/35), e.g., healthy diet, healthy food purchase, and general health behaviors (9/35), e.g., sunscreen use, sleeping patterns, stress reduction, sexual behaviors. In addition, six studies focused on managing diseases (e.g., reduced colorectal cancer risk, cardiac rehabilitation, hypertension, medication adherence) and reducing drug use (smoking cessation, alcohol consumption reduction).

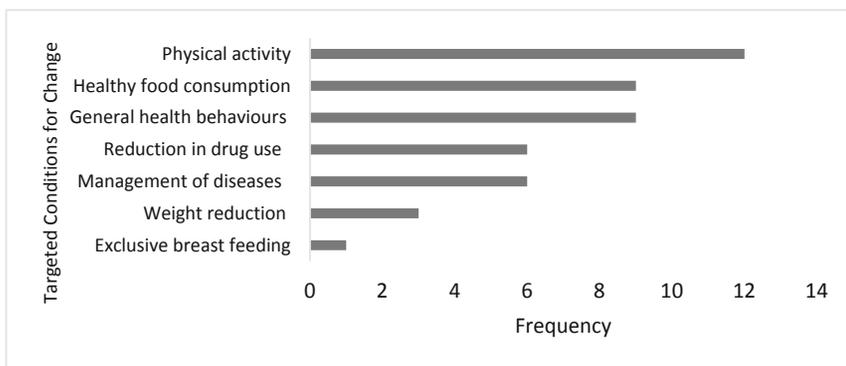


Fig. 2. Frequency of targeted outcomes for behavior change in the included studies

4.2 Modes of Delivery

Various digital modes are used to deliver the BCTs. Figure 3 shows that mobile applications have been prominently used mode of delivery (2013–2021). However, text messages/email/website, virtual agents, online video coaches declined after 2015. Use of social networks (e.g., Facebook, social media platforms), online systems (e.g., canteen system), messaging platforms (e.g., WhatsApp, WeChat), and wearables (e.g., pedometers) increased after 2016.

4.3 Utilization of BCTs

The taxonomy of behavior change techniques grouped 93 techniques into 16 groups. Only a few techniques were used from all intervention groups (Table 1), except the social support and social comparison groups. Moreover, approximately 75% of techniques were utilized from ‘*comparison of behaviors*’, ‘*comparison of the outcome*’, ‘*natural consequences*’, and ‘*goals and planning*’. Less than 50% of the techniques are

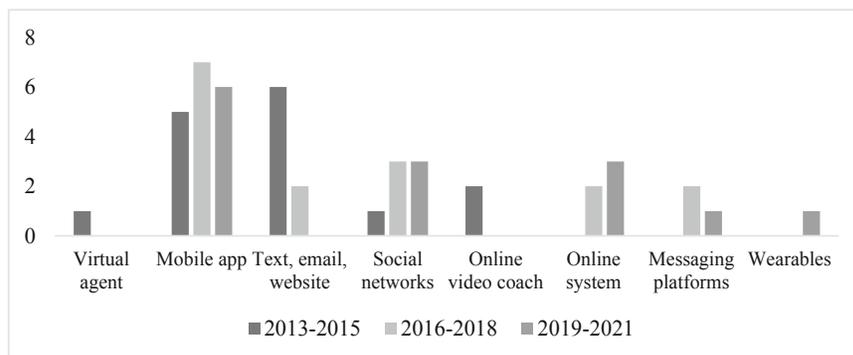


Fig. 3. Various modes to deliver digital interventions

used from other BCT groups, i.e., ‘*regulation*’, ‘*self-belief*’, ‘*identity*’, ‘*feedback and monitoring*’, ‘*repetition and substitution*’, ‘*associations*’ and ‘*reward and threat*’. None of the techniques were selected from ‘*antecedents*’, ‘*covert learning*’, and ‘*scheduled consequences*’.

Table 1. Frequency of Included intervention in the studies for each BCT Group

BCT groups	Included techniques in studies	Total techniques in the group
Social support	3	3
Comparison of behaviour	3	3
Comparison of outcomes	2	3
Covert learning	0	3
Shaping knowledge	2	4
Regulation	1	4
Self-belief	1	4
Identity	2	5
Natural consequences	4	6
Antecedents	0	6
Feedback and monitoring	2	7
Repetition and substitution	1	7
Associations	1	8
Goal and planning	6	9
Scheduled consequences	0	10
Reward and threat	3	11
Total	32	93

Only 32 out of 93 techniques were utilized in the included studies. Figure 4 represents the most and least frequently used BCTs in the included studies. The most frequently used BCTs are ‘prompts and cues’ (17/35 studies), ‘social support (unspecified)’ (15/35 studies), ‘goal setting (behaviour)’ (11/35 studies), and ‘self-monitoring of behavior’ (10/35 studies). Another important category, i.e., no BCT present, was coded in almost 12 studies (reflects that the strategy has been used for behavior change but cannot be given any code). All other techniques were included in one to six studies.

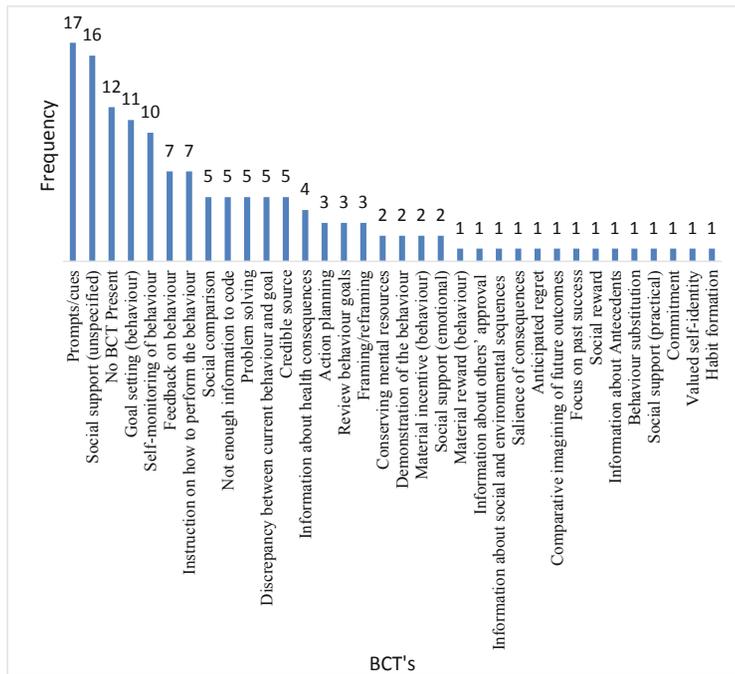


Fig. 4. Frequency of BCTs used in studies

4.4 Strategizing BCTs in Digital Interventions

Table 2 represents how BCTs were strategized/operationalized in digital interventions. All the strategies mentioned in the included studies were labeled using Taxonomy of behavior change techniques and summarized in Table 2.

Table 2. Strategies for various BCTs used in studies

BCTs & strategies	Target conditions
<i>Goal and planning</i>	
Goal setting (behavior) [21–31] - Goal setting using in-app calculators, personalized goal setting, predetermined goals, and tweak suggestions - Negotiating goals and developing plans using a virtual agent or digital health coach	Physical activity, Healthy food consumption, Weight reduction, General health behaviors
Review behavioral goals [24, 28, 30, 32] - Users report their goals on assigned activities using the in-app team features. The digital coach provides the feedback or through telephone sessions	Physical activity, Healthy food consumption, General health behaviors
Problem solving [27, 28, 33, 34] - In-app interactive tools, tailored textual/auditory messages were used to suggest problem-solving strategies - Telephone sessions with the coach to identify barriers and solutions - Apps helped to monitor habits/ triggers and methods to overcome habits	Healthy food consumption, Reduction in drug use, General health behaviors
Discrepancy between current behavior & goal [21, 30, 31] - Avatar-based dialogue to make the person aware of the discrepancy - Mobile applications visually showed the current state of the goal and selected goals	Healthy food consumption, Reduction in drug use, Physical activity
Action planning [33, 35] - Users created their action plan using the build-in app menu ‘action plan.’ - Mobile applications suggested action plans	Healthy food consumption, Physical activity
Commitment [29] - Participants were asked to change behavior by pledging social media	Weight reduction
<i>Feedback and Monitoring</i>	
Feedback on Behavior [23, 25, 27, 29, 32, 36, 37] - Feedback using visual/graphical display (bar chart, graphs, pie chart) via mobile applications and online systems - Personalized online feedback sessions delivered by health coaches	Healthy food consumption, General health behaviors, Weight reduction,

(continued)

Table 2. (continued)

BCTs & strategies	Target conditions
<p>Self-monitoring of behavior [23, 25, 26, 28–30, 34, 38–40]</p> <ul style="list-style-type: none"> - User transfer data related to health goals in mobile applications - Self-monitoring using wearables and build in-app tracking devices 	Physical activity, Healthy food consumption, General health behaviors, Weight reduction, Management of diseases
<i>Associations</i>	
<p>Prompts and cues [21–23, 25, 27, 29, 31, 34, 37, 38, 41–47]</p> <ul style="list-style-type: none"> - Sending reminders/prompts to perform health-related activities through mobile applications, calendar-based systems, email/text messages (WhatsApp), prompting questions, and daily challenges - Personalized reminders based on selected time/day by the users 	Reduction in drug use, Physical activity, Healthy food consumption, General health behaviors, Weight reduction
<i>Social support</i>	
<p>Social support (unspecified) [24, 28–30, 32–35, 38, 39, 42, 48–52]</p> <ul style="list-style-type: none"> - Support and encouragement through apps, text messages, testimonials, WhatsApp groups, and online community forums - Phone calls for counseling by clinicians and counselors - Clinicians or users were posting on Facebook or a team-based app 	Healthy food consumption, Reduction in drug use, Physical activity, Weight reduction, General health behaviors
<p>Social support (practical) [47]</p> <ul style="list-style-type: none"> - Nutritionists' posts provide answers in real-time using we chat 	Healthy food consumption
<p>Social support (emotional) [28, 37]</p> <ul style="list-style-type: none"> - Emotional support was provided by sending encouraging texts/calls to the users by the therapists 	General health behaviors, Management of diseases
<i>Comparison of behavior</i>	
<p>Social comparison [37, 40, 43, 53]</p> <ul style="list-style-type: none"> - Users were asked to post achieved goals on Facebook or in the mobile app (e.g., Bulletin board) 	Reduction in drug use, Physical activity, Weight reduction, General health behaviors
<p>Information on other's approval [31]</p> <ul style="list-style-type: none"> - Subjective roles correction in the form of gamified quiz 	Reduction in drug use

(continued)

Table 2. (continued)

BCTs & strategies	Target conditions
Demonstration of behavior [31] - Animated stories were used to demonstrate behaviors	Reduction in drug use
Rewards & threats	
Material rewards [53] - Water bottle and a healthy cookbook on number of footsteps and likes on Facebook was given; however, this is not the digital mode of delivery	Management of diseases
Social reward [51] - A positive feedback message through a mobile application was sent	Physical activity in type II diabetic patients
Material Incentive [43, 54] - Participants were informed that they could get free nicotine replacement therapy from NHS smoking services - Money incentives were also provided for attending the session. However, none of the studies utilized any digital form	Reduction in drug use
Self-belief	
Focus on past success [43] - A message was sent via the app after a period of successful attempts (both intentional and non-intentional)	Reduction in drug use
Comparison of outcomes	
Credible source [32, 34, 42, 44, 47] - Lectures by experts in WeChat - Personalized help was provided by experts (phone calls, email, and mobile app)	Management of diseases, Physical activity, Reduction in drug use, Healthy food Consumption
Comparative imagining of future outcomes [43] - Positive stories from peers about life after smoking cessation and a prompt to consider future outcomes	Reduction in drug use
Repetition and substitution	
Habit formation [33] Monthly follow-up moments are created to encourage respondents to revisit the app (non-digital)	Healthy food consumption

(continued)

Table 2. (continued)

BCTs & strategies	Target conditions
<p>Behavioral substitution [27]</p> <p>- Application suggesting context-specific replacement of behavior through a mobile application (e.g., where do it sit tool to suggest replacement of sitting behavior)</p>	General health behaviors
<i>Natural consequences</i>	
<p>Information on health consequences [31, 33–35, 47]</p> <p>- Information on health risk behaviors was sent via mobile applications (text), WeChat, and animated stories</p>	Physical activity, Healthy food consumption, Reduction in drug use
<p>Information on social and environmental consequences [31]</p> <p>- Presented a gamified quiz showing the consequence of drug use</p>	Reduction in drug use
<p>Salience of consequence [31]</p> <p>- Feedback on incorrect responses targeted correcting students' expectations about the drug's effect</p>	Reduction in drug use
<p>Anticipated regret [31]</p> <p>- Feedback on wrong answered responses targeted to increase awareness about the patient regret students may experience from drug use</p>	Reduction in drug use
<i>Regulation</i>	
<p>Conserving mental resources [33, 47]</p> <p>- Information on nutritional properties of oils, a list of fruits and vegetables, and recipes were uploaded in the mobile app</p>	Healthy food consumption
<i>Shaping Knowledge</i>	
<p>Instructions on how to perform a behavior [27, 30, 31, 34, 41, 43]</p> <p>- Animated stories and Text messages were sent to help users to learn behaviors</p> <p>- Mobile applications were used to teach various behaviors, e.g., Instructions on type and duration of exercise, estimating food portion, etc.</p>	Physical activity, Healthy food consumption, Reduction in drug use, General health behaviors
<p>Information on antecedents [27]</p> <p>- The mobile app provided information on behavior/emotional antecedents</p>	General health behaviors

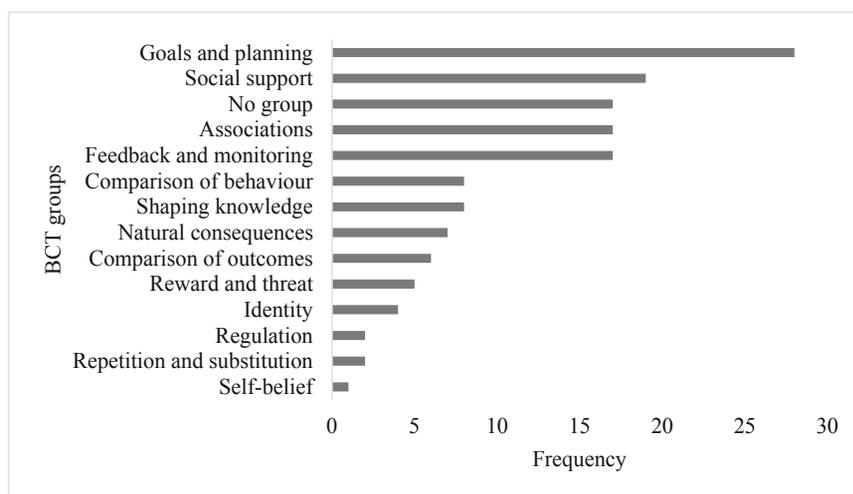
(continued)

Table 2. (continued)

BCTs & strategies	Target conditions
Identity	
Valued self-identity [31] - Story-telling exercise was suggested to produce self-statements of the life they want	Reduction in drug use
Framing [31, 43, 54] - Gamified quiz score to change expectations, altering beliefs using mobile applications and SNS	Reduction in drug use

4.5 Commonly Used BCT Groups

The 93 BCTs were combined into 16 groups. Figure 5 represents the frequency of different BCT groups used in studies. The most used group across studies were ‘*goals and planning*’, ‘*social support*’, ‘*feedback and monitoring*’, and ‘*associations*’. However, some of the studies also coded as ‘*No group*,’ i.e., either enough description was not available to code the strategy or the given description cannot be coded as strategy according to BCT taxonomy. ‘*Goals and planning*’ is the most frequently used group, and it is often combined with all other groups except ‘*comparison of behavior*’, ‘*reward and threat*’, and ‘*social support*’. ‘*Social support*’ is the second most frequently used group with all other groups except for ‘*comparison of behavior*’, ‘*identity*’, and ‘*self-belief*’. ‘*Associations*’ group is used with all other groups except for ‘*natural consequences*’. ‘*Feedback and monitoring*’ is used with most techniques except for ‘*shaping knowledge*’, ‘*reward and threat*’, ‘*regulation*’, and ‘*identity*’.

**Fig. 5.** Frequently used BCT groups in included studies

5 Discussion

The review aimed to explore how various BCTs were strategized in DHIs. 125 strategies were coded from 35 studies using behavior change taxonomy [15]. 33 behavior change techniques from taxonomy of 93 techniques were utilized in the included studies. The results indicated that the most frequently used techniques were ‘*prompts and cues*’, ‘*social support (unspecified technique)*’, ‘*goal setting (behavior technique)*’, and ‘*self-monitoring of behavior*’ (almost present in 10–17 studies). Previous reviews [16–19] also found these techniques most frequently used. However, some techniques used frequently in other literature reviews were not highlighted in the current review. For example, Lyons [18] found ‘*social comparison*’ and ‘*focus on the past success*’ as the most used techniques. Similarly, Dunn [19] also found ‘*information about health consequences*’ as the frequently used technique. Furthermore, the present study has not explored the link between various BCTs and intervention functions of BC. It is worth mentioning that ‘*Goal setting (behavior technique)*’ and ‘*self-monitoring of behavior*’ are the most frequently used techniques for different intervention functions such as enablement, education, training, incentivization/coercion. Similarly, ‘*social support (unspecified technique)*’ is the most frequently used technique for enablement, and ‘*prompts and cues*’ are mentioned as the most frequently used technique for education. Further studies need to specify the procedure of selecting BCTs to establish these links in more detail.

‘*Prompts and cues*’ was the most frequently used technique in the included studies. Sending reminders and notifications were the common strategies for ‘*Prompts and cues*’ (Table 2). ‘*Prompts and cues*’ are the stimuli designed to prompt action/reaction on specific behaviors from the users, also known as “Triggers” [55], in the form of SMS reminders/Push notifications/alerts. ‘*Prompts and cues*’ help to learn and elicit new behaviors through forming new routines. SMS are the excellent feasible source of electric reminders [56]; similarly, Push notifications allows the delivery of personalized alerts and timely updates through mobile application [36, 48]. In-depth personalization features can also be added to digital triggers; however, triggers could be a source of alert fatigue, habituation, or ignorance of triggers [55]. It is also essential to consider that only this technique from the ‘associations’ group has been used. Future studies are needed to explore new methods of strategizing other techniques from this group and in combination with other techniques.

‘*Social support (unspecified technique)*’ is the second most used technique defined as arranging social support (e.g., family, peers, or staff) related to behavior. The current review explored that encouragement and counselling were delivered through various social networks, phone, text messages, etc. (Table 2). Social support is one of the important factors for promoting behavior change [57]. The increased use of social media and messaging platforms have fostered a novel way of providing health-based interventions due to features such as, e.g., identity representation, peer grouping, and web-based social networking [58]. Various other modes of delivering social support such as via bulletin boards, or synchronous chat rooms, interactions in web-enabled interventions were also used in previous studies. Online support systems can also deliver techniques such as “social comparison”. In the current review, few studies used social media to encourage comparison and competition using bulletin boards, encouraging to post achieved goals on Facebook [27, 42].

Self-regulation is one of the critical mechanisms in behavior change. It can be improved through various techniques such as goal setting, self-monitoring of behavior, reviewing progress feedback on behavior, problem-solving, etc. [59]. ‘Goal Setting (behavior technique)’ and ‘self-monitoring’ were also prominent in the included studies. Various strategies have been employed to deliver goal setting, such as in-app calculators, personalized goal setting, and predetermined goals in mobile applications. However, digital interventions lack incorporating ‘action planning’ techniques (included only in three studies). Therefore, incorporating action planning features, i.e., detailed planning on the performance of the behavior, can improve intervention design and effectiveness. New technologies enable users to use modern self-monitoring methods, e.g., self-tracking devices, wearable devices, in-app sensors are now commonly used ways of monitoring ones’ behavior. Hennessy et al. [59] concluded that intervention components, such as self-monitoring, feedback, and goal setting, were successful, but their efficacy varied across health behaviors and populations. ‘Goals and planning’ is the most frequently used group in the included studies, and different strategies from ‘goals and planning’ and ‘feedback and monitoring’ were used in the included studies. It is important to note that goals and planning’ were not used with other ‘Reward and threat’ and “Social Support”. Goal setting along with rewards and support can help to improve intervention results.

Three studies delivered techniques using non-digital modes such as ‘material rewards’ by giving cookbooks/water bottles and ‘material incentives’ using monetary incentives [53]. Rewards are commonly used techniques in interventions for behavior change (improve motivation). They are classified into two major categories, i.e., tangible rewards (e.g., material/ financial reward) and non-tangible rewards (e.g., congratulatory messages). However, using tangible rewards (monetary/material rewards) within digital interventions for behavior change is relatively new. For example, Ahn [60] explored the effect of the points-based reward system in gamification on children’s physical activity. After successfully achieving the goals, children earned the points, and points can be used to buy more tricks for their virtual dogs. However, the results were not significant. Similarly, Mitchell [61] aimed to increase health knowledge rewarded users with loyalty points that can be redeemed for other consumables. Loyalty points can be earned through downloading the app, sharing with friends, and completing short education health quizzes. Therefore, new innovative strategies are needed to explore to deliver tangible rewards.

The focus of the current review was to explore behavioral change techniques that were strategized/implemented in digital interventions rather than the overall efficacy of the intervention techniques. However, only twenty-two studies reported the overall effectiveness of the intervention, out of which 14 studies suggested effective results. Few studies suggested improvement in the targeted outcomes but were not statistically significant, and effects declined over after some time [22, 48]. ‘Social comparison’, ‘material reward & incentive’, ‘information about health consequences’, ‘habit formation’, ‘social support (unspecified technique, emotional technique)’, ‘problem-solving’, ‘action planning’, ‘conserving mental resources’, ‘instruction on how to perform the behavior’, ‘prompts/cues’, ‘self-monitoring of behavior’, ‘goal setting (behavior technique)’, ‘Review behavior goals’, ‘Feedback on behavior’, ‘social, reward’, ‘framing/reframing’, ‘credible source’, and ‘discrepancy between current behavior and goal’

produced effective results. It should be noticed that most of these techniques were used only in a few studies in a combination of other techniques *and, in some cases, also produced non-effective results*. Two important categories emerged from the current review, i.e., ‘no BCT present’, for strategies that cannot be coded into any specific category, e.g., educational material delivered via text and video. In addition, limited information presented in the studies about the intervention’s descriptions resulted in another code, i.e., ‘not enough information to code’ for strategies, e.g., “goal setting, exercise scheduling and overcoming barriers”. Lastly, limited information was given on the exact content of the intervention, i.e., what exactly is sent in a text message as prompts and cues? Therefore, it is important to consider theories/frameworks of behavior change while selecting, strategizing, and reporting BCTs to produce effective and sustainable results. Furthermore, innovative ways of strategizing various BCTs are needed to be implemented in DHI.

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References

1. Webb, J., et al.: Preliminary outcomes of a digital therapeutic intervention for smoking cessation in adult smokers: randomized controlled trial. *JMIR Ment. Health* **7**(10), e22833 (2020). <https://doi.org/10.2196/22833>
2. Perski, O., Blandford, A., West, R., Michie, S.: Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis. *Transl. Behav. Med.* **7**(2), 254–267 (2016). <https://doi.org/10.1007/s13142-016-0453-1>
3. Cole-Lewis, H., Ezeanochie, N., Turgiss, J.: Understanding health behavior technology engagement: pathway to measuring digital behavior change interventions. *JMIR Formative Res.* **3**(4), e14052 (2019). <https://doi.org/10.2196/14052>
4. Fulton, E., Kwah, K., Wild, S., Brown, K.: Lost in translation: transforming behaviour change techniques into engaging digital content and design for the StopApp. *Healthcare* **6**(3), 75 (2018). <https://doi.org/10.3390/healthcare6030075>
5. Moller, A.C., et al.: Applying and advancing behavior change theories and techniques in the context of a digital health revolution: proposals for more effectively realizing untapped potential. *J. Behav. Med.* **40**(1), 85–98 (2017). <https://doi.org/10.1007/s10865-016-9818-7>
6. Michie, S., Fixsen, D., Grimshaw, J.M., Eccles, M.P.: Specifying and reporting complex behaviour change interventions: the need for a scientific method. *Implement. Sci.* **4**(1), 40 (2009). <https://doi.org/10.1186/1748-5908-4-40>
7. Zhang, S., Hamburger, E., Kahanda, S., Lyttle, M., Williams, R., Jaser, S.S.: Engagement with a text-messaging intervention improves adherence in adolescents with type 1 diabetes: brief report. *Diab. Technol. Ther.* **20**, 386–389 (2018). <https://doi.org/10.1089/dia.2018.0015>
8. Markowitz, J.T., et al.: Text messaging intervention for teens and young adults with diabetes. *J. Diab. Sci. Technol.* **8**, 1029–1034 (2014). <https://doi.org/10.1177/1932296814540130>
9. Conroy, D.E., Yang, C.-H., Maher, J.P.: Behavior change techniques in top-ranked mobile apps for physical activity. *Am. J. Prev. Med.* **46**, 649–652 (2014). <https://doi.org/10.1016/j.amepre.2014.01.010>

10. Ch, Y., Jp, M., De, C.: Implementation of behavior change techniques in mobile applications for physical activity. *Am. J. Prev. Med.* **48**, 452–455 (2015). <https://doi.org/10.1016/J.AMEPRE.2014.10.010>
11. Michie, S., Johnston, M., Francis, J., Hardeman, W., Eccles, M.: From theory to intervention: mapping theoretically derived behavioural determinants to behaviour change techniques. *Appl. Psychol.* **57**, 660–680 (2008). <https://doi.org/10.1111/J.1464-0597.2008.00341.X>
12. Mummah, S.A., Robinson, T.N., King, A.C., Gardner, C.D., Sutton, S.: IDEAS (integrate, design, assess, and share): a framework and toolkit of strategies for the development of more effective digital interventions to change health behavior. *J. Med. Internet Res.* **18**(12), e317 (2016). <https://doi.org/10.2196/jmir.5927>
13. Skivington, K., et al.: A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ* **374**, n2061 (2021). <https://doi.org/10.1136/bmj.n2061>
14. Michie, S., Atkins, L., West, R.: The behaviour change wheel: a guide to designing interventions. https://books.google.ee/books/about/The_behaviour_change_wheel_a_guide_to_de.html?id=1TGlrqEACAAJ&redir_esc=y. Accessed 03 May 2021
15. Michie, S., et al.: The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann. Behav. Med.* **46**, 81–95 (2013). <https://doi.org/10.1007/S12160-013-9486-6>
16. Morrissey, E.C., Corbett, T.K., Walsh, J.C., Molloy, G.J.: Behavior change techniques in apps for medication adherence: a content analysis. *Am. J. Prev. Med.* **50**, e143–e146 (2016). <https://doi.org/10.1016/J.AMEPRE.2015.09.034>
17. Simeon, R., et al.: Behavior change techniques included in reports of social media interventions for promoting health behaviors in adults: content analysis within a systematic review. *J. Med. Internet Res.* **22**(6), e16002 (2020). <https://doi.org/10.2196/16002>
18. Lyons, E.J., Lewis, Z.H., Mayrsohn, B.G., Rowland, J.L.: Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis. *J. Med. Internet Res.* **16**, e192 (2014). <https://doi.org/10.2196/JMIR.3469>
19. Dunn, E.E., Gainforth, H.L., Robertson-Wilson, J.E.: Behavior change techniques in mobile applications for sedentary behavior. *Digit. Health* **4**, 2055207618785798 (2018). <https://doi.org/10.1177/2055207618785798>
20. Schoeppe, S., et al.: Apps to improve diet, physical activity and sedentary behaviour in children and adolescents: a review of quality, features and behaviour change techniques. *Int. J. Behav. Nutr. Phys. Act.* **14**, 1–10 (2017). <https://doi.org/10.1186/S12966-017-0538-3/TABLES/2>
21. Lisetti, C., Amini, R., Yasavur, U., Rische, N.: I can help you change! An empathic virtual agent delivers behavior change health interventions. *ACM Trans. Manage. Inf. Syst.* **4**(4), 1–28 (2013). <https://doi.org/10.1145/2544103>
22. Damen, I., van den Heuvel, R., Brankaert, R., Vos, S.: Advancing digital behavior change interventions by exploring a calendar-based suggestion system; advancing digital behavior change interventions by exploring a calendar-based suggestion system. In: *European Conference on Cognitive Ergonomics 2021* (2021). <https://doi.org/10.1145/3452853>
23. Goodman, S., Morrongiello, B., Meckling, K.: A randomized, controlled trial evaluating the efficacy of an online intervention targeting vitamin D intake, knowledge and status among young adults. *Int. J. Behav. Nutr. Phys. Act.* **13**(1), 116 (2016). <https://doi.org/10.1186/s12966-016-0443-1>
24. Hartzler, A.L., et al.: Acceptability of a team-based mobile health (mHealth) application for lifestyle self-management in individuals with chronic illnesses. In: *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 3277–3281. *IEEE Engineering in Medicine and Biology Society* (2016). <https://doi.org/10.1109/EMBC.2016.7591428>

25. Bonn, S.E., Löf, M., Östenson, C.-G., Trolle Lagerros, Y.: App-technology to improve lifestyle behaviors among working adults - the Health Integrator study, a randomized controlled trial. *BMC Pub. Health* **19**, 273 (2019). <https://doi.org/10.1186/s12889-019-6595-6>
26. Recio-Rodríguez, J.I., et al.: Combined use of smartphone and smartband technology in the improvement of lifestyles in the adult population over 65 years: study protocol for a randomized clinical trial (EVIDENT-Age study). *BMC Geriatr.* **19**(1), 19 (2019). <https://doi.org/10.1186/s12877-019-1037-y>
27. Buman, M.P., et al.: BeWell24: development and process evaluation of a smartphone “app” to improve sleep, sedentary, and active behaviors in US Veterans with increased metabolic risk. *Transl. Behav. Med.* **6**(3), 438–448 (2015). <https://doi.org/10.1007/s13142-015-0359-3>
28. An, L.C., et al.: A randomized trial of an avatar-hosted multiple behavior change intervention for young adult smokers. *JNCI Monogr.* **2013**(47), 209–215 (2013). <https://doi.org/10.1093/jncimonographs/igt021>
29. Patrick, K., et al.: Design and implementation of a randomized controlled social and mobile weight loss trial for young adults (project SMART). *Contemp. Clin. Trials* **37**, 10–18 (2014). <https://doi.org/10.1016/j.cct.2013.11.001>
30. Pellegrini, C.A., et al.: Design and protocol of a randomized multiple behavior change trial: make better choices 2 (MBC2). *Contemp. Clin. Trials* **41**, 85–92 (2015). <https://doi.org/10.1016/j.cct.2015.01.009>
31. Vasiliou, V.S., Byrne, M., et al.: Reducing Drug-use Harms among Higher Education Students: X Contextual-Behaviour Change Digital Intervention Development Using the Behaviour Change Wheel (2020). <https://doi.org/10.21203/rs.3.rs-86503/v1>
32. Bell, D.L., et al.: Computer-assisted motivational interviewing intervention to facilitate teen pregnancy prevention and fitness behavior changes: a randomized trial for young men. *J. Adolesc. Health* **62**, S72–S80 (2018). <https://doi.org/10.1016/j.jadohealth.2017.06.015>
33. Elbert, S.P., Dijkstra, A., Oenema, A.: A mobile phone app intervention targeting fruit and vegetable consumption: the efficacy of textual and auditory tailored health information tested in a randomized controlled trial. *J. Med. Internet Res.* **18**, e147 (2016). <https://doi.org/10.2196/jmir.5056>
34. Garrison, K.A., et al.: Craving to quit: a randomized controlled trial of smartphone app-based mindfulness training for smoking cessation. *Nicotine Tob. Res.* **22**, 324–331 (2020). <https://doi.org/10.1093/ntr/nty126>
35. Recio-Rodríguez, J.I., et al.: Combined use of smartphone and smartband technology in the improvement of lifestyles in the adult population over 65 years: study protocol for a randomized clinical trial (EVIDENT-Age study). *BMC Geriatr.* **19**, 19 (2019). <https://doi.org/10.1186/s12877-019-1037-y>
36. Stacey, F., et al.: A cluster randomized controlled trial evaluating the impact of tailored feedback on the purchase of healthier foods from primary school online canteens. *Nutrients* **13**(7), 2405 (2021). <https://doi.org/10.3390/nu13072405>
37. Burner, E., et al.: Design and patient characteristics of the randomized controlled trial TExT-MED + FANS a test of mHealth augmented social support added to a patient-focused text-messaging intervention for emergency department patients with poorly controlled diabetes. *Contemp. Clin. Trials* **80**, 1–8 (2019). <https://doi.org/10.1016/j.cct.2019.03.003>
38. Forman, D.E., LaFond, K., Panch, T., Allsup, K., Manning, K., Sattelmair, J.: Utility and efficacy of a smartphone application to enhance the learning and behavior goals of traditional cardiac rehabilitation: a feasibility study. *J. Cardiopulm. Rehabil. Prev.* **34**, 327–334 (2014). <https://doi.org/10.1097/HCR.0000000000000058>
39. Hebden, L., Cook, A., van der Ploeg, H.P., King, L., Bauman, A., Allman-Farinelli, M.: A mobile health intervention for weight management among young adults: a pilot randomised controlled trial. *J. Hum. Nutr. Diet. Official J. Br. Diet. Assoc.* **27**, 322–332 (2014). <https://doi.org/10.1111/jhn.12155>

40. Lee, M.-K., Lee, D.Y., Ahn, H.-Y., Park, C.-Y.: A novel user utility score for diabetes management using tailored mobile coaching: secondary analysis of a randomized controlled trial. *JMIR Mhealth Uhealth* **9**, e17573 (2021). <https://doi.org/10.2196/17573>
41. Szabó, C., Ócsai, H., Csabai, M., Kemény, L.: A randomised trial to demonstrate the effectiveness of electronic messages on sun protection behaviours. *J. Photochem. Photobiol. B Biol.* **149**, 257–264 (2015). <https://doi.org/10.1016/j.jphotobiol.2015.06.006>
42. Chiang, N., Guo, M., Amico, K.R., Atkins, L., Lester, R.T.: Interactive two-way mHealth interventions for improving medication adherence: an evaluation using the behaviour change wheel framework. *JMIR Mhealth Uhealth* **6**(4), e87 (2018) <https://mhealth.jmir.org/2018/4/e87>. 6, e9187 (2018). <https://doi.org/10.2196/MHEALTH.9187>
43. Fulton, E., Brown, K., Kwah, K., Wild, S.: StopApp: using the behaviour change wheel to develop an app to increase uptake and attendance at NHS stop smoking services. *Healthcare* **4**(2), 31 (2016). <https://doi.org/10.3390/healthcare4020031>
44. Mackenzie, K., Goyder, E., Eves, F.: Acceptability and feasibility of a low-cost, theory-based and co-produced intervention to reduce workplace sitting time in desk-based university employees. *BMC Pub. Health* **15**, 1294 (2015). <https://doi.org/10.1186/s12889-015-2635-z>
45. Blake, H., Suggs, L.S., Coman, E., Aguirre, L., Batt, M.E.: Active8! technology-based intervention to promote physical activity in hospital employees. *Am. J. Health Prom. AJHP* **31**, 109–118 (2017). <https://doi.org/10.4278/ajhp.140415-QUAN-143>
46. Schmidtke, K.A., et al.: An exploratory randomised controlled trial evaluating text prompts in Lebanon to encourage health-seeking behaviour for hypertension. *Int. J. Clin. Pract.* **75**, e13669 (2021). <https://doi.org/10.1111/ijcp.13669>
47. Zhu, R., Xu, X., Zhao, Y., Sharma, M., Shi, Z.: Decreasing the use of edible oils in China using WeChat and theories of behavior change: study protocol for a randomized controlled trial. *Trials* **19**(1), 631 (2018). <https://doi.org/10.1186/s13063-018-3015-7>
48. Inauen, J., et al.: Using smartphone-based support groups to promote healthy eating in daily life: a randomised trial. *Appl. Psychol. Health Well Being* **9**, 303–323 (2017). <https://doi.org/10.1111/APHW.12093>
49. Looyestyn, J., Kernot, J., Boshoff, K., Maher, C.: A Web-based, social networking beginners' running intervention for adults aged 18 to 50 years delivered via a facebook group: randomized controlled trial. *J. Med. Internet Res.* **20**, e67 (2018). <https://doi.org/10.2196/jmir.7862>
50. Ramsey, R.R., et al.: A systematic evaluation of asthma management apps examining behavior change techniques. *J. Allergy Clin. Immunol. Pract.* **7**(8), 2583–2591 (2019). <https://doi.org/10.1016/j.jaip.2019.03.041>
51. Bonn, S.E., et al.: App-technology to increase physical activity among patients with diabetes type 2 - the DiaCert-study, a randomized controlled trial. *BMC Pub. Health* **18**, 119 (2018). <https://doi.org/10.1186/s12889-018-5026-4>
52. Oeldorf-Hirsch, A., High, A.C., Christensen, J.L.: Count your calories and share them: health benefits of sharing mHealth information on social networking sites. *Health Commun.* **34**, 1130–1140 (2019). <https://doi.org/10.1080/10410236.2018.1465791>
53. Key, K.V., Adegboyega, A., Bush, H., Aleshire, M.E., Contreras, O.A., Hatcher, J.: #CRCFREE: using social media to reduce colorectal cancer risk in rural adults. *Am. J. Health Behav.* **44**, 353–363 (2020). <https://doi.org/10.5993/AJHB.44.3.8>
54. Namkoong, K., Nah, S., Record, R.A., van Stee, S.K.: Communication, reasoning, and planned behaviors: unveiling the effect of interactive communication in an anti-smoking social media campaign. *Health Commun.* **32**, 41–50 (2017). <https://doi.org/10.1080/10410236.2015.1099501>
55. Muench, F., Baumel, A.: More than a text message: dismantling digital triggers to curate behavior change in patient-centered health interventions. *J. Med. Internet Res.* **19**(5), e147 (2017). <https://www.jmir.org/2017/5/e147>. 19, e7463 (2017). <https://doi.org/10.2196/JMIR.7463>

56. Hernández-Reyes, A., Molina-Recio, G., Molina-Luque, R., Romero-Saldaña, M., Cámara-Martos, F., Moreno-Rojas, R.: Effectiveness of PUSH notifications from a mobile app for improving the body composition of overweight or obese women: a protocol of a three-Armed randomized controlled trial. *BMC Med. Inform. Decis. Mak.* **20**, 1–10 (2020). <https://doi.org/10.1186/S12911-020-1058-7/FIGURES/4>
57. Greaney, M.L., Puleo, E., Sprunck-Harrild, K., Haines, J., Houghton, S.C., Emmons, K.M.: Social support for changing multiple behaviors: factors associated with seeking support and the impact of offered support. *Health Educ. Behav.* **45**, 198–206 (2018). <https://doi.org/10.1177/1090198117712333>
58. Elaheebocus, S.M.R.A., Weal, M., Morrison, L., Yardley, L.: Peer-based social media features in behavior change interventions: systematic review. *J. Med. Internet Res.* **20**(2), e20 (2018). <https://www.jmir.org/2018/2/e20>. 20, e8342 (2018). <https://doi.org/10.2196/JMIR.8342>
59. Hennessy, E.A., Johnson, B.T., Acabchuk, R.L., McCloskey, K., Stewart-James, J.: Self-regulation mechanisms in health behaviour change: a systematic meta-review of meta-analyses, 2006–2017. *Health Psychol. Rev.* **14**, 6 (2020). <https://doi.org/10.1080/17437199.2019.1679654>
60. Ahn, S.J. (Grace), Johnsen, K., Ball, C.: Points-based reward systems in gamification impact children’s physical activity strategies and psychological needs. *Health Educ. Behav.* **46**, 417–425 (2019). <https://doi.org/10.1177/1090198118818241>
61. Mitchell, M., et al.: Uptake of an incentive-based mHealth app: process evaluation of the carrot rewards app. *JMIR Mhealth Uhealth* **5**(5), e70 (2017). <https://mhealth.jmir.org/2017/5/e70>. 5, e7323 (2017). <https://doi.org/10.2196/MHEALTH.7323>



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Supporting Behaviour Change Techniques with Interaction Design Patterns

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Abstract. Design patterns provide a structured method for addressing common design problems by offering proven solutions that can be reused across different contexts. In the case of designing digital behaviour change interventions, interaction designers may face challenges in translating Behaviour Change Techniques (BCTs) knowledge into digital interventions. Interaction design patterns for BCTs can help overcome this challenge by providing descriptions, examples, rationale for using BCTs, and proven solutions. The current study examines six patterns for commonly used BCTs in digital interventions (reminder, social support, goal setting, self-monitoring, and instruction on performing behaviour and feedback on behaviour). The proposed design patterns were evaluated by four interaction design experts. They found the descriptions and examples provided in the design patterns to be clear and comprehensible. The experts appreciated the balance between concreteness and abstractness. The resulting design patterns can contribute to the informed design of digital behaviour change interventions and are helpful for designers, developers, researchers and product managers. Experts suggested that the language of the design patterns needs to be simplified for industry professionals to ensure that they can understand and apply them. Experts also indicated the need for shorter versions of the patterns, such as plain summaries or mind maps. Future design efforts to refine and simplify the proposed patterns and to develop additional patterns covering a broader range of BCTs are required.

Keywords: Design pattern · Behaviour change techniques · Interaction design

1 Problem Statement

The increased growth in the use of smartphone applications, wearable technologies and web-based systems presents promising avenues for supporting behaviour change, referred to as Digital Behaviour Change Interventions (DBCIs) for health [1]. Digital interventions aiming for behaviour change support often include reminders or notifications, options for setting goals, and monitoring of behaviour and feedback, also defined as Behaviour Change Techniques (BCTs) [2, 3]. BCTs are defined as active, observable, replicable, and irreducible components of an intervention designed to alter behaviours. They can be used alone or in combination with other BCTs [3]. Michie et al. [2] provided a taxonomy of ninety-three BCTs divided into sixteen groups. The taxonomy of

behaviour change techniques offers a structured and systematic way of understanding BCTs. For example, techniques that can be used for delivering different types of rewards and incentives (social reward, material reward, self-reward, material incentive, material reward) are grouped together as “rewards and incentives”. The taxonomy also provides theoretical definitions of these BCTs, examples, and how one BCT can be used with other BCTs [2, 3]. This taxonomy can facilitate the selection of techniques from a wide range of possible techniques and link BCTs with behaviour change theories. This further allows us to define and clearly explain the observable content of the technique (such as agreeing on a daily 45-min walk is the actual content for the goal-setting technique) in detail, making the replication of BCTs easy [2].

BCTs are strategised in the form of features in DBCIs, for example, *prompts and cues* can be strategised as in-app notifications or reminder messages to support behaviour change [4]. Users interact with these features to support behaviour change, which means that these need to be carefully designed and aligned with theoretical definitions of BCTs. The current theoretical knowledge of BCTs lacks comprehensive practical guidelines on strategising BCTs in DBCIs [5–7]. Thompson et al. (2016) mentioned that the adoption and application of BCTs are fragmented, selected, and combined on an ad-hoc basis for designing DBCIs [8]. Studies have found a disparity between the intended and selected BCT, and the content of the BCTs is not matched with the mentioned BCT) [4, 9–15]. Farhat-ul-Ain [4] found that the techniques used in some studies cannot be coded with any BCT listed in the taxonomy (No BCT present), reflecting that BCTs are not strategised appropriately. This indicates a need for better practical interaction design guidelines and systematic approaches to overcome the challenge of translating theoretical knowledge of BCTs and strategising them into digital interventions for designers [9].

Interaction design as a field focuses on designing interactive behaviour or user interactions with digital and non-digital products [16]. *Design patterns* offer predefined solutions or models used in the interaction design to address common user problems. These design patterns include repeatable solutions, providing a set of rules or best practices for designing interactive systems. They serve as successful design solutions recognised by professionals in the field, offering guidance to designers, developers, evaluators, and users involved in the design and implementation of interactive systems [17, 18]. This work aimed to overcome the challenge of translating theoretical knowledge of BCTs and strategising them into digital interventions by proposing design pattern collections for BCTs.

In the current work, we proposed six design patterns for commonly used BCTs highlighted in a literature review [4] and evaluated them with experts. The authors assume that the pattern approach could facilitate the process of strategising BCTs by providing designers with a common language, terminology, structure and reusable solutions. The research questions for the current study are:

1. How can design patterns be developed to help designers strategise behaviour change techniques in digital behaviour change interventions?
2. To what extent do interaction design experts perceive proposed design patterns BCTs as understandable, helpful and acceptable?

To address these research questions, we first developed six design patterns for six commonly used BCTs highlighted in the previous review [4]. The design patterns were further evaluated by interaction design experts.

2 Brief Overview of Design Patterns

Alexander et al. [19] coined the concept of design patterns in the field of architecture. Alexander proposed three essential patterns' elements: a *context*, a *problem*, and a *solution* [19]. The context is a recurrent collection of scenarios in which the pattern can be used. The problem represents a set of forces, such as goals and limitations, that exist in the context. In general, the problem specifies when to use the pattern. The solution indicates a design form or rule that may be used to resolve the forces. The same pattern concept is also applied in the field of interaction design, more broadly, where the primary objective is to create interactive systems that are useful and usable for users [20]. Seffah et al. [17] mentioned that design patterns provide solutions to common design problems, offering best practices for designing interactive systems. It is a simple method of documenting design knowledge, readable for designers, developers, and other stakeholders, based on knowledge (not created artificially), and captures essential principles of good design by telling the designer what to do and why. Typically, patterns are presented in a predefined and should include the problem-context-solution construct, but the overall structure may vary [18–20]. Some examples of design patterns include interaction patterns [18], user interface patterns [21], and Yahoo! Pattern Library [22]. The design patterns approach allows professionals and non-professionals to decide how to proceed and help to go forward with a design while enhancing communication and knowledge-sharing among people collaborating on a design project. It is a valuable approach for conveying and sharing experience and knowledge [23].

3 Design Patterns for Behaviour Change Techniques

The published literature on behaviour change techniques typically provides theoretical definitions of BCTs and examples for the application of these techniques in face-to-face settings. For interaction designers, this literature is not helpful enough to translate knowledge on behaviour change techniques into digital behaviour change interventions [2]. Design patterns can provide reusable solutions to interaction designers to help them select appropriate BCTs and strategise them in digital interventions. For the current study, the authors designed six patterns for selected commonly used BCTs identified in the recent review [4]. In this review, the authors coded behaviour change techniques used in DBCIs for health by using the taxonomy of behaviour change techniques used in thirty-five studies. The authors provided a comprehensive list of how these BCTs were strategised in DBCIs and found that six techniques are more frequently used (prompts and cues, social support (unspecified-mainly relating to advising someone or providing non-contingent reward rather than providing any practical or emotional support), goal-setting, self-monitoring of behaviour, feedback on behaviour, and instructions on how to perform behaviour) compared to others [4]. The current work is focused on developing design patterns for these most used BCTs.

Various pattern structures have been approached [18–20, 22]. Tidwell’s structure of pattern documentation was selected because it contains a clear structure and elements, such as the name of the design pattern, examples, and an extensive explanation of why and how they can be utilised in the design and solution that can be used in various contexts [18]. Some elements were added to Tidwell’s structure to contextualise it according to BCTs. “Design Principle and Theory” establishes a link between behaviour change theory and techniques. “BCT combinations” indicate how various BCTs are often combined. The authors attempted to support each design pattern element with relevant literature. A brief overview of elements included in Tidwell’s approach and elements added by the authors is presented in Table 1:

Table 1. Structure of Tidwell Design Pattern Adapted for Behaviour Change Techniques.

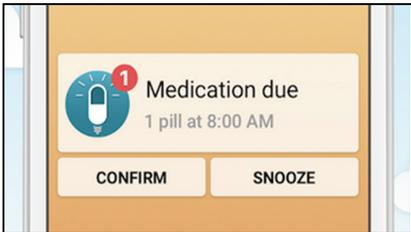
Elements	Purpose
Pattern Name	Define pattern name
Code/BCT name (Group) in Taxonomy	BCT’s name and group are mentioned in the BCT Taxonomy
Illustrative example	Screenshots of instantiated. In our case, it presents carefully selected images of BCTs strategised in digital interventions
What (Problem)	A short problem statement to specify the user needs where BCT can be used
Use when	Conditions in which patterns can be used
How	Represents the solution in the pattern for the BCT
Why	Provide the design rationale for BCT
Design principle and theory	Establishes the link between pattern, behaviour change theory and technique
BCTs combinations	Elaborate how BCTs can be combined with other techniques
In other collections	Directs to similar patterns in other collections, potentially offering new insights or examples

The following section provides six proposed design patterns (prompts and cues techniques, social support (Unspecified) techniques, goal-setting techniques, instructions on how to perform behaviour, feedback on behaviour technique, self-monitoring of behaviour) in detail (3.1, 3.2, 3.3, 3.4, 3.5 and 3.6). All design patterns follow the same structure as presented in Table 1.

3.1 Design Pattern for “Prompts and Cues Technique”

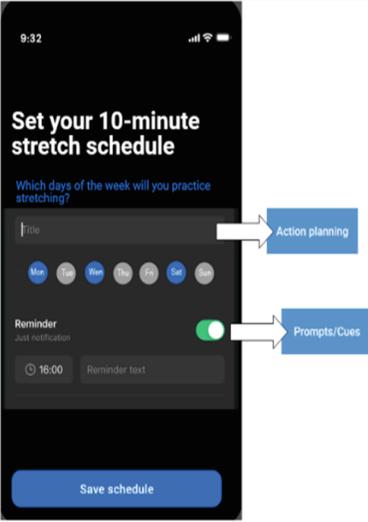
The most common behaviour change technique identified in the review was the “prompts and cues technique” [4]. It is typically strategised as notifications, emails, text messages, hyperlinks, calendar events, images, and auditory signals, often synchronised with the time or location of behaviour performance. It includes employing specific stimuli to capture and direct an individual’s attention towards a particular direction. This stimulus enhances an individual’s capacity to retain information, focus selectively on environmental cues, and make decisions among multiple options. The design pattern for the Prompts and Cues Technique is provided in Table 2.

Table 2. Design Pattern for Prompts and Cues Technique.

<p>Pattern Name: Reminder (alternative names: Prompt, Trigger, Cue, Call to action, Request)</p> <p>Code/BCT name (Group) in Taxonomy: 7.1 Prompts/Cues (Associations)</p>	
<p>Examples: AppleWatch reminder, activityApp, myTherapyApp, StretchClock</p>	
	
	
<p>What (Problem): Users may have trouble remembering to perform or focus on some tasks during a certain period. Users want to be reminded, informed, or motivated about the tasks or activities to form a new habit or routine or not to perform undesired ones.</p>	
<p>Use when: Introduce to users a prompt or cue that can be used as a reminder to act or react in the direct context. This is useful when the user needs to be reminded or motivated to take some action in a specific context (e.g., take medication, remind a doctor’s appointment, take a standing pause to reduce sitting time, etc.) or rethink a planned or ongoing activity (e.g., take stairs instead of elevator, reduce speed, drink water instead of soda).</p>	
<p>How: Use notifications or prompts to encourage specific behaviour, such as taking medication at scheduled times. These reminders can be personalised and triggered based on user-defined settings or environmental cues. Reminders could be event-based or time-based. ‘Reminder’ could be user-generated, system-generated or generated by another person involved (e.g., a healthcare specialist). When designing, it is important to consider that these triggers may lead to alert fatigue, habituation, or user disregard of triggers [24].</p>	
<p>Why: If ‘Reminder’ matches the time and the context – then the user is more likely to be motivated and able to take a needed action or complete a task.</p>	
<p>Design Principle and Theory: Behaviour change technique ‘Prompts/Cues’ as an intervention component is linked with Theoretical Domain Framework constructs ‘Memory, attention and decision processes’ and ‘Environmental context and resources’, therefore influences memory, attention, attention control, decision making, cognitive overload/tiredness [25]. Technique supports a person’s ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives.</p>	

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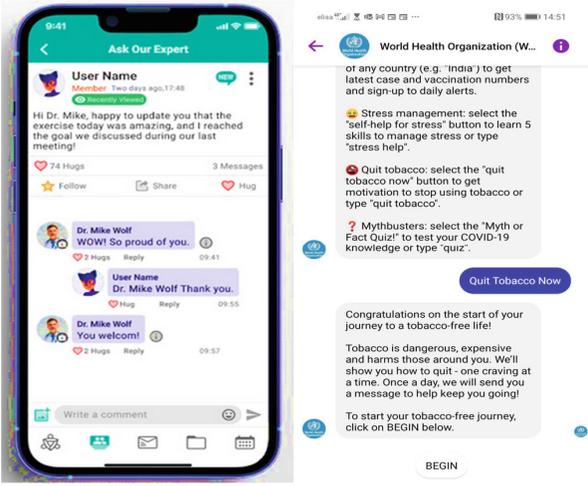
Table 2. (continued)

<p>BCTs combinations: When a stimulus is linked to a specific action in an if-then plan including one or more of frequency, duration or intensity “Action planning” can be applied.</p>	
<p>In other collections: Trigger – Fogg’s Behavior change model (https://behaviormodel.org/prompts/), Reminding – Designing Social Interfaces: Principles, Patterns, and Practices for Improving the User Experience [22]</p>	

3.2 Design Pattern for “Social Support (Unspecified) Technique”

The second most used BCT is ‘Social support (unspecified), which involves providing advice, arranging, or offering support from various sources such as friends, relatives, or colleagues, as well as non-contingent praise or rewards for behaviour performance. It is commonly delivered through social networks, apps with guidance messages, text messages, testimonials, WhatsApp groups, online forums, and phone counselling. The design pattern for the “Social Support (Unspecified) Technique” is provided in Table 3.

Table 3. A “Social Support (Unspecified) Technique”.

<p>Pattern Name: Social network Code/BCT name (Group) in Taxonomy: 3.1. Social Support (unspecified)</p>
<p>Examples Belong MS app, WHO Facebook chat-bot</p>

<p>What (Problem): When a person tries to achieve something (target behaviour), he expects to receive various types of social support, such as praise, advice, encouragement, or guidance, through an intervention platform.</p>
<p>Use when: When designing interventions to support individuals in achieving target behaviours, it's essential to encourage interaction with the content and foster collaboration among users with mutual goals. This can be accomplished by creating engaging content that prompts participants to interact, such as liking, sharing, and commenting on posts, as demonstrated by Patrick et al. [26] in their study on Facebook content. Additionally, providing a medium for users to form groups and support each other is crucial. For instance, Inauen et al. [27] successfully used WhatsApp chat groups where participants encouraged each other to achieve their eating goals. ‘Social Support’ should be clearly defined in the design in terms of how it is delivered— in a group or individually, and from whom - family members, friends, specialists, and group members with the same goal; and demonstrate a connection to the target behaviour.</p>
<p>How: An intervention platform to deliver social support related to the user’s target behaviour can use various digital channels, social networks, mobile applications, text messages, testimonials, messenger groups (WhatsApp), online community forums, phone calls, and chatbots. Support providers could be - family members, friends, caregivers, group members, and the community, or the system itself (digital intervention) could offer support via images, symbols, and software-generated dialogues.</p>
<p>Why: If a person receives ‘Social support’ as recognition and appreciation by others of his personal efforts and achievements, then he/she most likely will be motivated to learn and progress through their behaviour change plan.</p>
<p>Design Principle and Theory: ‘Social support’ as an intervention component is linked with the Theoretical Domain Framework construct ‘Social influences’ – defined as a change in one’s</p>

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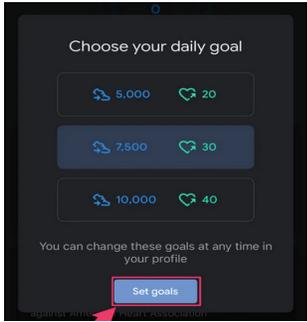
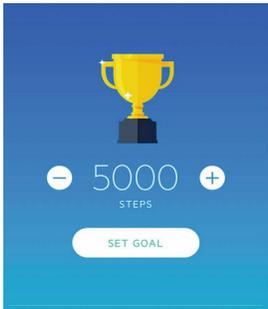
Table 3. (continued)

<p>beliefs, behaviour, or attitudes caused by external pressures, whether real or imagined [25]. Three types of social support are defined: emotional, informational, and instrumental [2].</p>	
<p>BCTs combinations: To enhance the performance of a target behaviour, it is beneficial to advise on, arrange, or provide emotional, social support. This support can come from various sources, including friends, relatives, colleagues, "buddies," or staff.</p>	
<p>In other collections: Praise Design Pattern – https://ui-patterns.com/patterns/Praise Software pattern: cooperation [28]</p>	

3.3 Design Pattern for “Goal Setting Technique”

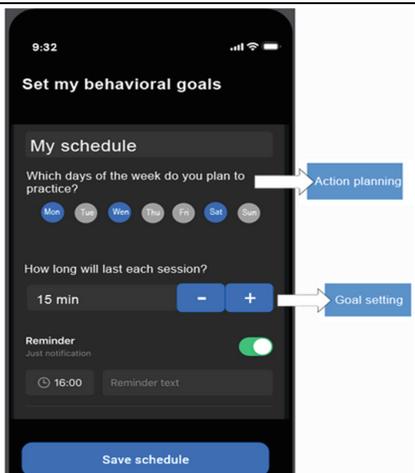
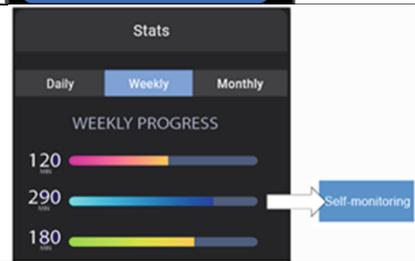
The third most used BCT was the “goal-setting technique”, which helps users define their goals. It often includes features for setting specific, measurable, and time-bound objectives. It is often combined with other techniques, such as “feedback on behaviour” and “self-monitoring of behaviour”, which offer to monitor themselves and provide feedback on progress and adjustments to goals based on performance. The design pattern for the “goal-setting technique” is provided in Table 4.

Table 4. Design Pattern for “Goal Setting Technique”.

<p>Pattern Name: Goal Scheduler</p> <p>Code/BCT name (Group) in Taxonomy: Goal setting (behaviour) (Goals and planning)</p>
<p>Examples: Google Fit app, MoveSum app</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div>
<p>What (Problem): Digitally supported interventions enable users to establish behaviour-oriented goals tailored to their intentions within the intervention platform. Users have the capability to define specific behavioural objectives aligned with their desired outcomes within the digital intervention setting. This feature empowers users to personalise their goals based on individual preferences and motivations, fostering engagement and facilitating targeted behaviour change efforts.</p>
<p>Use when: Pattern ‘Goal setting’ helps users to achieve specific behavioural changes or desired outcomes. Useful for establishing habitual behaviours that contribute to achieving desired outcomes effectively and sustainably. In interventions, patterns can be set by either the target user themselves or by experts designing goals on behalf of the target user. Collaborative approaches, where users receive expert guidance in selecting appropriate goals, can ensure that goals are tailored to individual needs and capabilities. This method promotes personalised goal setting that aligns with individual circumstances, enhancing the likelihood of successful behaviour change.</p>
<p>How: When setting goals within an intervention platform, it is crucial to ensure they are specific, measurable, realistic, achievable, time-based, and directly relevant to the target behaviour. Using in-app calculators and virtual agents and synchronising with popular calendar platforms like Google Calendar or iCal can enhance goal management and tracking. This diversified approach supports structured and systematic goal setting, thereby increasing the efficacy of behaviour change interventions.</p>
<p>Why: Goals help individuals plan and motivate their intention to achieve desired outcomes. They focus attention away from irrelevant tasks and towards behaviours that are relevant to achieving the goal.</p>

(continued)

Table 4. (continued)

<p>Design Principle and Theory: Behaviour change technique ‘Goal setting’ refers to Theoretical Domain Framework constructs such as ‘Intention’ and ‘Goals’. Technique supports a person’s ability to decide consciously to perform a behaviour or a resolve to act in a certain way and provides the mental representations of outcomes, or end states that an individual wants to achieve [25].</p>	
<p>BCT combinations: The Behaviour Change Technique (BCT) taxonomy suggests that goal setting within interventions is more effective when accompanied by "Action planning" and "Self-monitoring of behaviour." "Action planning" involves specifying details like frequency, duration, or intensity of desired behaviour, while "Self-monitoring" means tracking progress towards goals. Integrating detailed behavioural planning and ongoing monitoring significantly enhances intervention effectiveness. Self-monitoring can be facilitated through self-tracking devices, wearable technology, or in-app sensors, providing feedback to users on their progress. This alignment with evidence-based strategies optimises the impact of behaviour change interventions on user outcomes [2].</p>	
	
<p>In other collections: Reduction & Tunnelling – Fogg’s Persuasive Design Principles [29], Goal-Gradient Effect – https://ui-patterns.com/patterns/Completion</p>	

3.4 Design Pattern for “Self-monitoring of Behaviour Technique”

The fourth most used BCT was the “goal-setting technique”, which helps users individuals observe and document their actions as part of an effort to modify behaviour. It involves the systematic collection of pertinent health information, exemplified by participants modifying their smoking tracker based on daily cigarette consumption [30, 31]. The design pattern for “self-monitoring of behaviour” is provided in Table 5.

Table 5. Design Pattern for “Self-monitoring of Behaviour”.

<p>Pattern Name: Behavioural Tracker</p> <p>Code/BCT name (Group) in Taxonomy: 2.3 Self-monitoring of behaviour (Feedback and monitoring)</p>			
<p>Examples: Kwit app for smoking cessation</p>			
			
<p>What (Problem): Individuals frequently encounter challenges in maintaining awareness of their actions and progress towards their desired health objectives. Adopting the practice of</p>			

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Table 5. (continued)

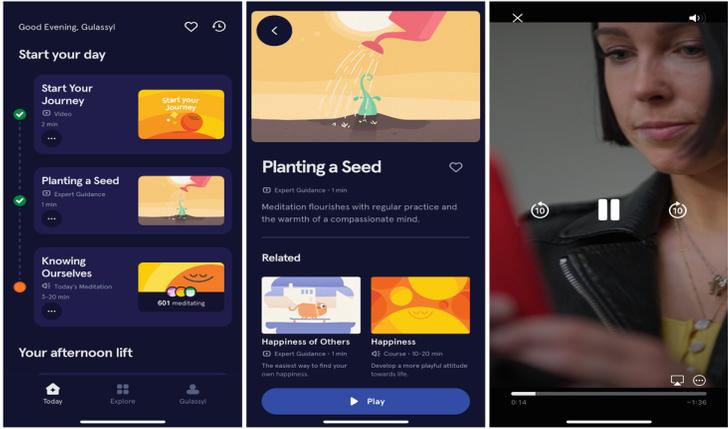
<p>"self-monitoring of behaviour," which involves actively tracking and documenting activities relevant to health goals, can facilitate informed decision-making and facilitate positive behavioural changes. Tang et al. [32] mentioned that self-monitoring enhances users' self-awareness regarding their actions and motivations, motivating them to reconsider their habits and intentions towards change</p>	
<p>Use when: It is useful for systematically tracking and visually representing key parameters of behaviour. It is especially beneficial for individuals managing chronic conditions like diabetes or obesity or those aiming to adopt healthier habits. Additionally, it helps transform new habits, such as improving diet and reducing sedentary screen time, into automated routines, reducing the need for extensive self-regulation [33]. As self-regulation improves, individuals can better prioritise physical activity, integrate new habits, and pursue additional goals, enhancing behaviour change efforts.</p>	
<p>How: Include an in-app journaling feature to help users document their behaviour and implement real-time behaviour monitoring options (for example, wearable technology) [30]. Simplify the self-monitoring methods to reduce recording frequency to enhance user adherence [34].</p>	
<p>Why: Self-monitoring increases awareness of behaviour and facilitates deliberate decision-making. Self-monitoring is a reliable method for sustaining user engagement and adherence to goals [32].</p>	
<p>Design Principle and Theory: 'Self-monitoring' is associated with the theoretical construct 'behaviour regulation' in the Theoretical Domain Framework. It involves efforts to control or alter objectively observed or measured behaviour [25].</p>	
<p>BCT combinations: Self-monitoring of behaviour outcomes corresponds to code 2.4, labelled "self-monitoring of outcome(s) of behaviour". This involves individuals monitoring and evaluating the outcomes of their activities. Monitoring conducted by others without feedback aligns with code 2.1, identified as "Monitoring of behaviour by others without feedback". Here, a third party analyses or records behaviour without providing feedback to the individuals. Monitoring by someone else with feedback based on behaviour outcomes is classified as code 2.7, described as "Feedback on the outcome(s) of behaviour". This includes scenarios where individuals receive feedback from third parties based on monitored behaviour outcomes [2].</p>	
<p>In Other Collection: Self-monitoring - https://ui-patterns.com/patterns/self-monitoring. Self-monitoring - Persuasive Systems Design: Key Issues, Process Model, and System Features [35].</p>	

3.5 Design Pattern for “Instructions on How to Perform a Behaviour Technique”

The fifth most used BCT was “instructions on how to perform a behaviour,” which involves offering advice and instruction on behaviour execution, often including skills

training. This technique equips individuals with the expertise and skills necessary to achieve desired objectives. The design pattern for “instructions on how to perform behaviour” is provided in Table 6.

Table 6. Design Pattern for “Instructions on How to Perform Behaviour”.

<p>Pattern Name: Guided task assistance</p> <p>Code/BCT name (Group) in Taxonomy: 4.1. Instruction on how to perform the behaviour (Shaping knowledge)</p>
<p>Examples Headspace</p> <p>Headspace provides instructions from the first interaction with the app, akin to a roadmap that offers its users dynamic, step-by-step guidance for meditation</p> 
<p>What (Problem): Key challenges individuals face when adopting desired behaviours include the lack of knowledge, misconceptions, and behaviour complexity.</p>
<p>Use when: Crucial in guiding individuals on specific behaviours, particularly when users lack knowledge or expertise in certain areas. The instructional components in mobile applications are important in assisting users in implementing behaviours effectively [36]. Providing relevant information on behaviours enhances user knowledge and reduces frustrations associated with behaviour adoption.</p>
<p>How: Offer interactive or visual guides (e.g., animations, videos, or text) that explain each step in performing the behaviour, implement in-app tutorials that can be revisited anytime, and provide ongoing reminders with clear, actionable instructions and animated presentations to help users learn new knowledge and behaviour. This pattern enhances the likelihood of successful behaviour change by offering clear guidance, breaking tasks into manageable steps, accelerating skill acquisition, and providing solutions to obstacles [36–38]. Enhance user engagement with infographics and user stories to simplify instructions and improve comprehension [39].</p>

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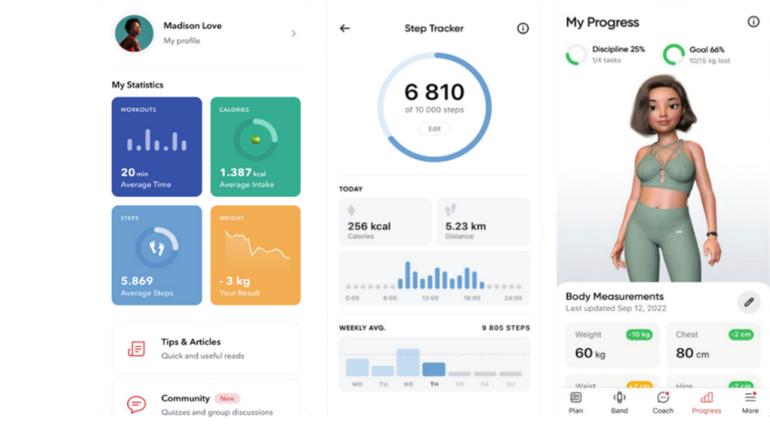
Table 6. (continued)

<p>Why: Pattern empowers users with essential knowledge on the significance of specific actions and how to integrate them effectively into daily life, facilitating informed decision-making and progress towards goals. Pattern offers simple guidance to overcome difficulties and barriers and enhances users' self-awareness. By providing tips, strategies, and suggestions, these instructions help users navigate obstacles and stay on course towards achieving their goals. These integrated strategies create a comprehensive, user-centric approach to instruction design, promoting successful intervention adherence.</p>
<p>Design Principle and Theory: “Instructions on how to perform a behaviour” is linked to the theoretical concept of “knowledge” within the Theoretical Domain framework. This technique encompasses both general knowledge, including awareness of the condition or scientific reasoning, and procedural knowledge [25].</p>
<p>BCT combinations: To enhance this pattern, combined with BCT under code 8.1, “Behavioral practice/rehearsal,” repeated practice is suggested to improve skills. And BCT under code 6.1, “Demonstration of the behaviour,” involves learners receiving detailed demonstrations and then practising by observing and replicating what they saw, which can be effective [2].</p> <div style="border: 1px solid black; padding: 5px;"> <p>The screenshot shows a mobile app interface for a 'Cat Pose' tutorial. At the top, the time is 08:39 and the title is 'Cat Pose'. Below the title is a large image of a person in a cat pose. Underneath are three smaller thumbnail images of the same pose from different angles. To the right of these thumbnails is a blue callout box with an arrow pointing to them, labeled 'Demonstration of the behavior'. Below the thumbnails is a list of details: 'Beginner', 'Difficulty', 'Core, Shoulders, Back', 'Muscle Groups', 'None', 'Equipment', and 'Step 1'. Below 'Step 1' is the instruction: 'Begin on all fours with your hands under your shoulders and your knees under your hips.' To the right of this instruction is another blue callout box with an arrow pointing to it, labeled 'Instructions on how to perform a behavior'.</p> </div>
<p>In Other Collection: Wizard - https://ui-patterns.com/patterns/Wizard</p>

3.6 Design Pattern “Feedback on Behaviour Technique”

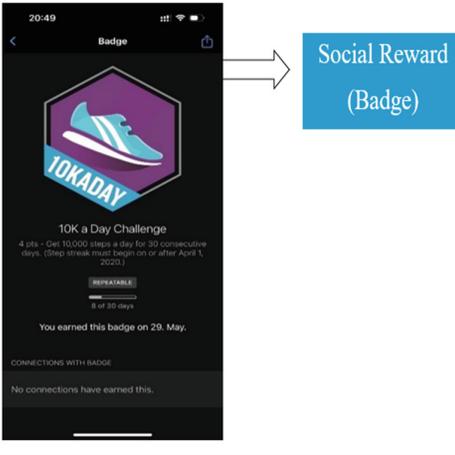
The sixth most used BCT was the “feedback on behaviour technique”, which provides evaluative feedback on behaviour performance, considering factors like its form, frequency, duration, and intensity. It is often combined with goal-setting and reward techniques. The design pattern for feedback on behaviour” is provided in Table 7.

Table 7. Design Pattern for “Feedback on Behaviour Technique”.

<p>Pattern Name: Progress Feedback</p> <p>Code/BCT name (Group) in Taxonomy: 2.2 Feedback on behaviour (Feedback and monitoring)</p>
<p>Examples: BetterMe health coaching app</p> 
<p>What (Problem): The pattern “Feedback on behaviour” in apps addresses the problems of improving user engagement, motivating desired actions, and facilitating behaviour change by providing users with real-time insights, guidance, and accountability. This ultimately leads to more informed decision-making and positive outcomes.</p>
<p>Use when: Useful when individuals need to be more aware of their behaviours, enabling them to track progress, identify patterns, and make necessary adjustments. To help individuals gauge their progress, celebrate successes, and address behaviours that need improvement. To reinforce desired behaviours and correct undesired ones. To encourage healthier choices and lifestyle changes. To help individuals understand areas of strength and areas needing development, fostering continuous improvement.</p>
<p>How: Using visual representations, behaviour-specific feedback messages, timely feedback delivery, convenient access to feedback, personalised feedback on individual data, and regular summaries can be used to strategise “Feedback on behaviour” [26, 38, 40–42]. Providing users with control over feedback types and also helping users understand feedback.</p>
<p>Why: Feedback on behaviour is crucial because it enables individuals to assess their actions about their goals and objectives, facilitating self-management and behavioural control. By receiving feedback and reviewing goals based on that feedback, individuals can make informed adjustments to their behaviours, aligning them more effectively with desired outcomes.</p>
<p>Design Principle and Theory: “Feedback on behaviour” is linked to the theoretical concept of “behavioural regulation” within the Theoretical Domain Framework. It entails systematic efforts focused on controlling or altering objectively observable and measurable behaviours [25].</p>

(continued)

Table 7. (continued)

<p>BCT combinations: The pattern can be combined with “Monitoring of behaviour by others without feedback”(BCT code 2.1), which involves observing an individual's behaviour without providing explicit feedback, such as when a fitness coach tracks activity levels but does not comment on performance. Conversely, “Social reward” (BCT code 10.4) involves giving praise or recognition for behaviour, such as a fitness app awarding badges or providing encouragement when a user achieves their daily step goal [2].</p>	
<p>In Other Collection: Completeness Meter - https://ui-patterns.com/patterns/Completeness-Meter Praise/Reward - Persuasive Systems Design: Key Issues, Process Model, and System Features [35].</p>	

4 Evaluation of Design Patterns

The expert evaluation was conducted to assess the understandability, helpfulness and acceptability of the design patterns. Semi-structured interviews were conducted with four interaction design experts. Three experts did not have a specific understanding of behaviour change theories but were aware of persuasive technologies and proficient in understanding design patterns (E1, E3, E4). One expert had a theoretical understanding of behaviour change theories and also had a background in designing digital interventions for behaviour change (E2). Wurhofer et al. (2010) provided a structured method to assess design patterns and divided into three broader criteria evaluation [43].

- **Understandability:** This criterion addresses ease in the understandability of the pattern, and comprehensibility of each pattern's element (such as its name, the problem it solves, etc.).
- **Helpfulness:** It suggests that the pattern needs to be helpful for the designers, meaning that the pattern description provides enough information for the user to understand how to apply it in practice.
- **Overall Acceptability:** This indicates to what extent the user believes in the pattern and is in agreement with its content.

Interview questions (Table 8) were prepared based on the criteria mentioned above [43]. The approach ensures a thorough evaluation and allows experts to evaluate and address critical points in design patterns.

Proposed design patterns and interview questions were sent to experts three days before the interview date. This gave the experts enough time to review and evaluate

Table 8. Semi-Structured Interview Questions for Expert Evaluation.

Criteria	Interview Questions
Understandability	How clear and understandable are the descriptions in the elements and examples provided in the design patterns for behaviour change techniques? (Sub-questions focused on understanding overall comprehensibility, language, balance between concreteness and abstractness of the design and ambiguity in the design Patterns)
Helpfulness	To what extent does the design pattern benefit you in facilitating your design process or addressing the design of specific behaviour change techniques? (Sub-questions focused on capturing relevant information, contribution to the development of improved designs for behaviour change interventions, and helpfulness in facilitating communication among designers, developers and researchers)
Overall Acceptability	Do you find yourself nodding in agreement as you read the pattern descriptions of BCTs, or does any design pattern description need to be improved? Considering your expertise and experience, how likely will you incorporate these design patterns into your future projects?

design patterns. The following results were generated by analysing the qualitative data for each evaluative criterion using a deductive thematic analysis approach. The data was analysed using predetermined categories of the evaluative criteria (understandability, helpfulness and overall acceptability).

4.1 Understandability of the Design Patterns for Behaviour Change

All experts mentioned that descriptions and examples provided in the design patterns for BCTs were clear, understandable and comprehensible. They found no ambiguity in the descriptions. One expert (E2) mentioned that: – “...*the content seems clean, and it was easy to read. I didn’t have any difficulties... Yeah, there is no ambiguity in the description*”.

The experts provided several suggestions for improving the understandability of design patterns. All experts (E1, E2, E3, E4) suggested that the language of the design patterns needs to be simplified for non-academics or young professionals or designers. As one of the experts (E1) mentioned: – “*I would say that if you’re aiming for a general professional audience, I would reformulate those or create an alternative version written in plain language, not like a simplified version, but maybe in a more professional manner. It’s just the question of lingo—academics use certain lingo, and then industry people use certain lingo*”. All Experts suggested that alternative versions need to be created with simpler language, shorter text with more precision in content, reducing several in-text citations, and giving brief explanations of examples can improve the comprehensibility of beginner designers as well as reduce the amount of time spent reading them. One expert mentioned the need for more images for different types of user interfaces (e.g., desktop) as they are currently more focused on mobile applications.

One expert (E2) suggested that another section should include words for caution and explain what not to do when strategising specific BCTs, for example, when to avoid sending reminders or not using reminders (prompts and cues): – *“I think it would be nice to have... not to use one, or like when to avoid”*. It is intended to allow designers to learn about the dos and don'ts of strategising BCTs in DBCIs. For example, in some cases, giving two of three meaningful choices to the user is enough rather than giving a lot of choices, or in conditions when some BCTs are not useful.

The expert suggested re-organising different design pattern elements considering the designers' limited time. As the expert (E3) mentioned: – *“My goal as a designer is to find a design (solution) as fast as possible; I don't want to spend hours reading it. I want to find my problem. And what can I do (solution)? And then, if I want to understand, like, why?”*. This indicates that the re-organisation of elements, such as mentioning the problem and solution before “use when”, can be a better approach for designers who want to review the problem and solution in a short period of time.

One expert (E2) suggested that game cards or puzzles can be used further to simplify these design patterns: – *“When I read it, I thought maybe it would be nice to have (something) like cards, like game cards, and you combine them... If you have a problem, you put it together like a puzzle, and it recreates another product and stuff”*. The experts (E1, E2, E4) suggested that a visual summary of the design patterns, such as infographics, leaflets, mind maps, or roadmaps, would help designers to understand them better. Lastly, one expert (E4) added that the element named “Design principle and theory” could be misleading for designers as these are not design principles but descriptions of the theory. It could be renamed as “related behaviour change theory”.

All experts agreed that the design patterns have balance in concreteness and abstractness: – *“Yes, definitely. I think it has a balance...I was paying attention to that when I was reading to see if it was too specific or too abstract. It was in the middle to me, so okay (E1)”*.

Overall, the result indicated that design patterns are comprehensible but need more simplified language for better clarity and understanding.

4.2 Helpfulness of Design Patterns

The experts acknowledged that the proposed design patterns could potentially improve designs for behaviour change interventions. The expert (E2) mentioned that adding a BCT combination in the design pattern is very helpful: – *“...BCT Combinations. It was really good as well. I really like that because sometimes, just triggering or notifying stand-alone (BCTs) doesn't work”*. Another expert added: – *“When reading, I already felt this inspiration spark that, aha! Yes, yes, this could be used”*. This indicates the potential helpfulness of the design patterns.

One expert (E1) mentioned that designers could use these patterns for validation purposes: – *“We just intuitively feel that this would be the best way to design this user story, for instance. So in terms of validation, this would be, I think, very useful”*. Moreover, the expert added that the proposed patterns are more related to *what needs to be designed* rather than the specific methods of how to design it. These can be used in the earlier phase of the design process (eliciting requirements) and can be viewed as requirements for BCTs.

The design patterns for BCTs can be useful for researchers, designers and developers. The expert (E1) mentioned: – *“Both developers and designers, I think, developers even more, really like manuals and doing everything by the book”*. It is interesting to note that experts highlighted the need to simplify design patterns and still mentioned that developers are interested in manuals (which require more time to read). However, one expert (E4) disagreed with the potential usefulness of the patterns for developers: – *“They will expect that you will explain how the system should work. Yeah, so not about like this... It’s still more about user experience”*. It highlights differences in the opinion of experts related to the potential use of design patterns by developers.

One expert (E3) highlighted that most designers are unaware that they actually design for behaviour change. These design patterns could be useful for them by looking at the problem and solution supported by knowledge of psychology and design. Overall, the experts agreed that the proposed design patterns are problem-focused, capture relevant knowledge, and are helpful in designing DBCIs for health.

4.3 Overall Acceptability of the Proposed Design Patterns

The experts found the design patterns acceptable and considered using them in their future projects. As one expert expressed (E1): – *“Aha!” Yes, yes, this could be. This could be used”*. In summary, the design patterns for BCTs are understandable, helpful and acceptable. The results indicated that the language needs to be simplified for industry professionals.

5 Conclusion

Design patterns are widely accepted in interaction design to represent design knowledge in a reusable format and avoid “reinventing the wheel” repeatedly. This work aimed to overcome the challenge of translating theoretical knowledge of BCTs and strategising them into digital interventions due to insufficient guidance for interaction designers. In the current work, we proposed six design patterns tailored for six BCTs for designing digital health behaviour change interventions.

Tidwell’s design patterns structure [18] was utilised and adapted in the context of BCTs. Elements such as code and BCT name in taxonomy, design principle and theory and BCT combination are added to the patterns’ structure to contextualise design patterns for BCTs. Klansja et al. [44] mentioned that re-usable solutions of BCTs could be a “win-win” solution for designers, behaviour change experts and developers. The expert evaluation results indicate the potential usefulness and helpfulness of the proposed design patterns. The expert evaluation suggested simplifying the language for industry professionals and adding additional elements that can highlight what not to do and words of caution when strategising BCTs. Crumblish et al. [22] also added similar elements like “special cases” in proposed design patterns for social interfaces. The authors consider it as an important suggestion because designers need to be cautious about different dos and don’ts when strategising BCTs in DBCIs. For example, the concept of satiation highlights that the effectiveness of rewards diminishes over time if they become too predictable or routine. This reflects that receiving rewards every time after hitting the

goals may reduce the value of rewards over time. To avoid such instances, designers can use BCTs such as scheduled rewards. Adding such guidelines to design patterns would enhance the design of the DBCIs.

The authors assume that provided patterns could help researchers and practitioners aiming to design digital interventions for behaviour change, not “start from scratch” or search through a large amount of literature. Design patterns can be used as a reference to analyse the existing solutions and understanding of behaviour change principles and theories. The patterns “Why” and “Design principle and Theory” sections allow designers to understand the rationale behind the pattern application in a specific context. For example, if the user forgets to perform some task or needs additional guidance, she can be prompted to take action by “reminder”. The patterns can also used to analyse and validate existing solutions for behaviour change.

Design patterns are supposed to support multidisciplinary communication. However, the results indicated differences in the opinion of their usefulness for developers. We assume that design patterns will provide a common language for discussion among teams, help developers understand the primary intent of BCTs, and ensure that the work of interaction designers is aligned with the work of software developers.

The authors assume that the proposed design patterns can inform interaction design practitioners in designing evidence-based and theory-based digital interventions for behaviour change. Future research should focus on simplifying the proposed design patterns and extending their taxonomy by developing design patterns for other BCTs.

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References

1. Dicianno, B.E., et al.: Perspectives on the evolution of mobile (mHealth) technologies and application to rehabilitation. *Phys. Ther.* **95**, 397 (2015). <https://doi.org/10.2522/PTJ.20130534>
2. Michie, S., et al.: The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Ann. Behav. Med.* **46**, 81–95 (2013). <https://doi.org/10.1007/S12160-013-9486-6>
3. Michie, S., Atkins, L., West, R.: *The Behaviour Change Wheel: A Guide To Designing Interventions*. Silverback Publishing, London (2014)
4. Farhat ul Ain, Popovit, O., Tomberg, V.: Mapping behavior change wheel techniques to digital behavior change interventions: review. In: Kurosu, M. (ed.) *HCII 2022. LNCS*, vol. 13304, pp. 277–295. Springer, Cham. (2022). https://doi.org/10.1007/978-3-031-05412-9_20
5. Truelove, S., Vanderloo, L.M., Tucker, P., Di Sebastiano, K.M., Faulkner, G.: The use of the behaviour change wheel in the development of ParticipACTION’s physical activity app. *Prev. Med. Rep.* **20**, 101224 (2020). <https://doi.org/10.1016/J.PMEDR.2020.101224>
6. Konstanti, C., Karapanos, E., Markopoulos, P.: The behavior change design cards: a design support tool for theoretically-grounded design of behavior change technologies. *Int. J. Hum. Comput. Interact.* **38**, 1238–1254 (2022). <https://doi.org/10.1080/10447318.2021.1990519>

7. Michie, S., Prestwich, A.: Are interventions theory-based? Development of a theory coding scheme. *Health Psychol.* **29**, 1–8 (2010). <https://doi.org/10.1037/A0016939>
8. Thomson, C., Nash, J., Maeder, A.: Persuasive design for behaviour change apps: Issues for designers. In: Proceedings of the Annual Conference of the South African Institute of Computer Scientists and Information Technologists (SAICSIT 2016), article 43, Johannesburg, South Africa, pp. 1–10 (2016). <https://doi.org/10.1145/2987491.2987535>
9. Fulton, E.A., Kwah, K.L., Wild, S., Brown, K.E.: Lost in translation: transforming behaviour change techniques into engaging digital content and design for the StopApp. *Healthcare.* **6** (2018). <https://doi.org/10.3390/HEALTHCARE6030075>
10. Morrissey, E.C., Corbett, T.K., Walsh, J.C., Molloy, G.J.: Behavior change techniques in apps for medication adherence: a content analysis. *Am. J. Prev. Med.* **50**, e143–e146 (2016). <https://doi.org/10.1016/J.AMEPRE.2015.09.034>
11. Simeon, R., et al.: Behavior change techniques included in reports of social media interventions for promoting health behaviors in adults: content analysis within a systematic review. *J. Med. Internet Res.* **22** (2020). <https://doi.org/10.2196/16002>
12. Lyons, E.J., Lewis, Z.H., Mayrsohn, B.G., Rowland, J.L.: Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis. *J. Med. Internet Res.* **16**, e192 (2014). <https://doi.org/10.2196/JMIR.3469>
13. Dunn, E.E., Gainforth, H.L., Robertson-Wilson, J.E.: Behavior change techniques in mobile applications for sedentary behavior. *Digit. Health* **4**, 205520761878579 (2018). <https://doi.org/10.1177/2055207618785798>
14. Conroy, D.E., Yang, C.-H., Maher, J.P.: Behavior change techniques in top-ranked mobile apps for physical activity. *Am. J. Prev. Med.* **46**, 649–652 (2014). <https://doi.org/10.1016/j.amepre.2014.01.010>
15. Cowan, L.T., et al.: Apps of steel: are exercise apps providing consumers with realistic expectations?: a content analysis of exercise apps for presence of behavior change theory. *Health Educ. Behav.* **40**, 133–139 (2013). <https://doi.org/10.1177/1090198112452126>
16. Cooper, A., Reimann, R., Cronin, D., Noessel, C., Csizmadi, J., Lemoine, D.: *About Face The Essentials of Interaction Design Fourth Edition*. Wiley (2014)
17. Seffah, A.: The evolution of design patterns in HCI: from pattern languages to pattern oriented design. In: Proceedings of the 1st International Workshop on Pattern Driven Engineering of Interactive Computing Systems (PEICS 2010), Berlin, Germany, pp. 4–9 (2010). <https://doi.org/10.1145/1824749.1824751>
18. Tidwell, J., Brewer, C., Valencia, A.: *Designing Interfaces: Patterns for Effective Interaction Design*. O'Reilly Media, Sebastopol (2010)
19. Alexander, C., et al.: *A Pattern Language: Towns, Buildings, Construction*. Oxford University Press, New York (1977)
20. Borchers, J.O.: Pattern approach to interaction design. In: Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS, pp. 369–378 (2000). <https://doi.org/10.1145/347642.347795>
21. Laakso, S.A.: *User interface design patterns* (2003). <https://www.cs.helsinki.fi/u/salaakso/patterns/>
22. Crumlish, C., Malone, E.: *Designing Social Interfaces*. O'Reilly Media, Inc. (2015)
23. Iba, T., Isaku, T.: A pattern language for creating pattern languages: 364 patterns for pattern mining, writing, and symbolizing. In: Proceedings of the 23rd Conference on Pattern Languages of Programs (PLoP 2016), vol. 11, pp. 1–63 (2016). <https://doi.org/10.5555/3158161.3158175>
24. Muench, F., Baumel, A.: More than a text message: dismantling digital triggers to curate behavior change in patient-centered health interventions. *J. Med. Internet Res.* **19**, e147 (2017). <https://doi.org/10.2196/jmir.7463>

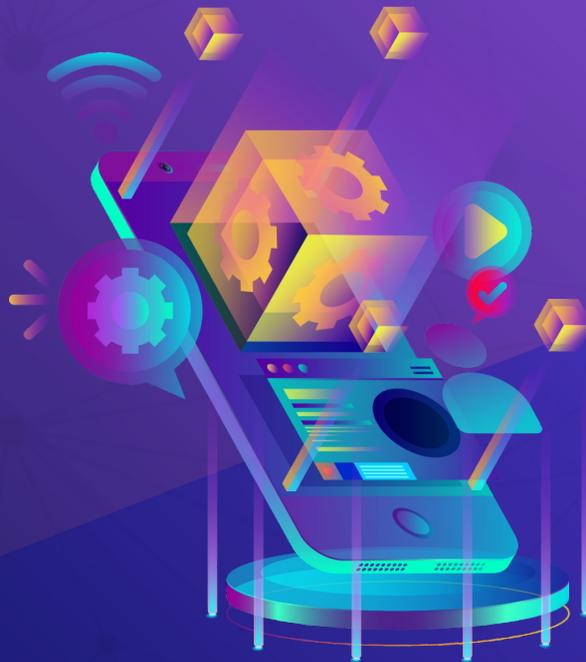
25. Atkins, L., et al.: A guide to using the theoretical domains framework of behaviour change to investigate implementation problems. *Implement. Sci.* **12**, 1–18 (2017). <https://doi.org/10.1186/s13012-017-0605-9>
26. Patrick, K., et al.: Design and implementation of a randomized controlled social and mobile weight loss trial for young adults (project SMART). *Contemp. Clin. Trials* **37**, 10–18 (2014). <https://doi.org/10.1016/J.CCT.2013.11.001>
27. Inauen, J., et al.: Using smartphone-based support groups to promote healthy eating in daily life: a randomised trial. *Appl. Psychol. Health Well Being* **9**, 303–323 (2017). <https://doi.org/10.1111/APHW.12093>
28. Oduor, M., Alahäivälä, T., Oinas-Kukkonen, H.: Persuasive software design patterns for social influence. *Pers. Ubiquit. Comput.* **18**, 1689–1704 (2014). <https://doi.org/10.1007/s00779-014-0778-z>
29. Fogg, B.J.: *Persuasive Technology: Using Computers to Change What We Think and Do*. Persuasive Technology: Using Computers to Change What We Think and Do, pp. 1–282. Morgan Kaufmann, San Francisco (2003)
30. Garrison, K.A., et al.: Craving to quit: a randomized controlled trial of smartphone app-based mindfulness training for smoking cessation. *Nicotine Tob. Res.* **22**, 324–331 (2020). <https://doi.org/10.1093/ntr/nty126>
31. Lee, M.-K., Lee, D.Y., Ahn, H.-Y., Park, C.-Y.: A novel user utility score for diabetes management using tailored mobile coaching: secondary analysis of a randomized controlled trial. *JMIR Mhealth Uhealth* **9**, e17573 (2021). <https://doi.org/10.2196/17573>
32. Tang, J., Abraham, C., Stamp, E., Greaves, C.: How can weight-loss app designers’ best engage and support users? A qualitative investigation. *Br. J. Health Psychol.* **20**, 151–171 (2015). <https://doi.org/10.1111/BJHP.12114>
33. Pellegrini, C.A., Hoffman, S.A., Collins, L.M., Spring, B.: Optimization of remotely delivered intensive lifestyle treatment for obesity using the multiphase optimization strategy: opt-IN study protocol. *Contemp. Clin. Trials* **38**, 251–259 (2014). <https://doi.org/10.1016/j.cct.2014.05.007>
34. Goodman, S., Morrongiello, B., Meckling, K.: A randomized, controlled trial evaluating the efficacy of an online intervention targeting vitamin D intake, knowledge and status among young adults. *Int. J. Behav. Nutr. Phys. Act.* **13**, 1–13 (2016). <https://pubmed.ncbi.nlm.nih.gov/27836017/>
35. Oinas-Kukkonen, H., Harjumaa, M.: Persuasive systems design: key issues, process model, and system features. *Commun. Assoc. Inf. Syst.* **24**, 485–500 (2009). <https://doi.org/10.17705/1CAIS.02428>
36. Vasiliou, V.S., Dockray, S., Dick, S., et al.: Reducing drug-use harms among higher education students: MyUSE contextual-behaviour change digital intervention development using the behaviour change wheel. *Harm Reduct. J.* **18**, 56 (2021). <https://doi.org/10.1186/s12954-021-00491-7>
37. Szabó, C., Ócsai, H., Csabai, M., Kemény, L.: A randomised trial to demonstrate the effectiveness of electronic messages on sun protection behaviours. *J. Photochem. Photobiol. B.* **149**, 257–264 (2015). <https://doi.org/10.1016/J.JPHOTOBIOL.2015.06.006>
38. Buman, M.P., et al.: BeWell24: development and process evaluation of a smartphone “app” to improve sleep, sedentary, and active behaviors in US Veterans with increased metabolic risk. *Transl. Behav. Med.* **6**, 438–448 (2016). <https://doi.org/10.1007/s13142-015-0359-3>
39. Fulton, E.A., et al.: StopApp: using the behaviour change wheel to develop an app to increase uptake and attendance at NHS stop smoking services. *Healthcare.* **4**(2), 31 (2016). <https://doi.org/10.3390/HEALTHCARE4020031>
40. Nibbeling, N., Simons, M., Sporrel, K., Deutekom, M.: A focus group study among inactive adults regarding the perceptions of a theory-based physical activity app. *Front. Public Health* **9**, 528388 (2021). <https://doi.org/10.3389/fpubh.2021.528388>

41. Bell, D.L., et al.: Computer-assisted motivational interviewing intervention to facilitate teen pregnancy prevention and fitness behavior changes: a randomized trial for young men. *J. Adolesc. Health*. **62**, S72–S80 (2018). <https://doi.org/10.1016/j.jadohealth.2017.06.015>
42. Stacey, F., et al.: A cluster randomized controlled trial evaluating the impact of tailored feedback on the purchase of healthier foods from primary school online canteens. *Nutrients*. **13** (2021). <https://doi.org/10.3390/nu13072405>
43. Wurhofer, D., Obrist, M., Beck, E., Tscheligi, M.: Introducing a comprehensive quality criteria framework for validating patterns. In: *Proceedings of the 2009 Computation World: Future Computing, Service Computation, Cognitive, Adaptive, Content, Patterns*, Athens, Greece, pp. 242–247 (2009). <https://doi.org/10.1109/COMPUTATIONWORLD.2009.86>
44. Klasnja, P., Hekler, E.B., Korinek, E.V., Harlow, J., Mishra, S.R.: Toward usable evidence: optimizing knowledge accumulation in HCI research on health behavior change. In: *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI 2017)*, Denver, Colorado, USA, pp. 3071–3082 (2017). <https://doi.org/10.1145/3025453.3026013>

APPENDIXES

APPENDIX 1

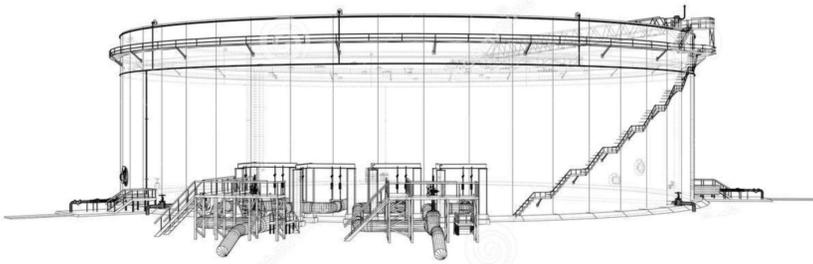
DHBC-DIGITAL HEALTH BEHAVIOUR CHANGE TOOLKIT FOR INTERACTION DESIGNERS



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Gulassyl Amirgaliyeva – Vladimir Tomberg

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PURPOSE OF
THE TOOLKIT



The Digital Behaviour Change (DIBEC) toolkit is designed to support interaction designers in systematically integrating behaviour change theory into the design of Digital Behaviour Change Interventions (DBCIs) for health. It offers a structured approach to integrating theoretical insights into design processes.



THE TOOLKIT INCLUDES:

- 1** *Theory-Enriched User Research Topic Guide Template* informed by behaviour change models, to help uncover relevant psychological and contextual factors;
- 2** *Theory-Enriched User Persona Template*, bridging the gap between research findings and design decisions; and
- 3** *A set of Design Patterns for Behaviour Change Techniques*, providing practical, reusable strategies for translating behavioural insights into concrete interaction design solutions.

Together, these components enable the development of user-centred, theory-driven, and operationally grounded products for digital health interventions that are both evidence-based and context-sensitive.



SECTION I

THEORY ENRICHED TOPIC GUIDE FOR CONDUCTING USER RESEARCH

The Theory-Enriched Topic Guide Template is designed to support designers in planning and conducting user research for digital behaviour change interventions. It's built around the COM-B model and the transtheoretical model of change, which helps you understand the key determinants that influence behaviour—people's capability, opportunity, and motivation to do something. The guide includes prompt questions to explore across all COM-B domains. These can help elicit what might be helping or stopping users from changing their behaviour.

Protocol for using and adapting the Theory-Enriched Topic Guide for Conducting User Research

1. Get familiar with the COM-B model, Behaviour Change Wheel in detail and the transtheoretical Model of Change. The references to key literature are provided at the end of this section I.
2. Begin by clearly specifying the target audience and the target behaviour the intervention aims to change. Ensure the behaviour is observable, measurable, and context-specific (e.g., "taking a 10-minute walk after lunch every weekday"). Michie et al. (2014) provided detailed guidelines on the selection of target behaviour with detailed worksheets. This includes the first phase of the Behaviour Change Wheel (Understand the Behaviour). This is critically important as these details will be used during the interview/focus groups and the user persona.
3. Read questions based on the COM-B model (Table 1) and the Transtheoretical Model of Change (Table 2).
4. Replace [perform specific behaviour] with specific target health behaviour selected for DBCIs.



5. Adjust the phrasing of questions to match the participant's language and context, but retain the intent behind the behavioural concept. For example, the question related to social opportunity: Can you describe any social norms or expectations that affect whether or not you [perform specific behaviour]?" Can be tailored in a way, "Are there any expectations in your family or social circle about what you should eat? How do those affect your food choices?"
6. Use the topic guide as a flexible framework to stay focused, but avoid reading it word-for-word—listen actively, adapt to the participant's language, and let the conversation flow naturally.
7. Add tailored follow-up questions (if needed). Initial responses can often be brief or vague. Follow-up questions help clarify what the participant means in detail.
8. All questions based on the COM-B model (Table 1) should be asked because they each target distinct and essential domains influencing behaviour: Capability, Opportunity, and Motivation. Exploring these domains is crucial for fully understanding the behavioural context.
9. Questions should be used more flexibly for the Transtheoretical Model of Change (Table 2). If the participant's response already reveals their current stage—e.g., "I'm thinking about making a change, but I haven't started planning yet," which clearly indicates the Contemplation stage—then it is not necessary to ask questions related to later stages (e.g., Action or Maintenance). Instead, focus on understanding their current stage in depth.
10. Designers can ask more related questions, such as about general routines and habits, technology preferences, motivators, etc. This topic guide will serve the purpose of eliciting determinants of behaviour and the stage of change. However, more generic questions are often required for designing products. Those questions can be added and probed in more detail.



Table 1. Questions based on the COM-B Model

COM-B -Based Questions		Purpose
	<p>Physical Capability</p> <p>1. What are the different physical skills or abilities (physical strength, stamina) required to perform [perform specific behaviour]? Do you have those skills?</p> <p>2. Are there any physical health conditions or limitations that affect your ability to perform certain tasks related to [perform specific behaviour]?</p>	Intended to support an understanding of physical limitations and capabilities that can influence behaviour.
	<p>Psychological Capability</p> <p>1. What kind of knowledge is required to [perform specific behaviour]? Do you have the knowledge required to [perform specific behaviour]?</p> <p>2. What kind of mental skills are required, such as, the ability to resist urges, keep things in mind (nor forget) and make appropriate decisions to [perform specific behaviour]? Do you have those mental skills to [perform specific behaviour]?</p> <p>The interviewer can break down questions into sub-questions focusing on one mental skill in one question.</p>	Intended to support understanding of current knowledge, memory, attention, and decision-making processes that can influence behaviour.
	<p>Social Opportunity</p> <p>1. Can you describe any social norms or expectations that impact [performing specific behaviour]?</p> <p>2. Are there any social support systems or networks that could help you [perform specific behaviour] more effectively?</p>	Intended to support understanding of social influences, norms, and social pressures that can influence behaviour.
	<p>Physical Opportunity</p> <p>1. Are there any physical barriers or constraints in your environment that impact [performing specific behaviour]??</p> <p>2. To what extent do resources such as time, money, and accessibility of health services facilitate/ hinder [performing specific behaviour]??</p>	Intended to support understanding of the availability and accessibility of resources, such as time and money, that can influence behaviour.
	<p>Reflective Motivation</p> <p>1. How do you perceive the consequences of [performing specific behaviour]?</p> <p>2. Can you describe any beliefs or attitudes that influence your decision-making regarding [performing specific behaviour]?</p> <p>3. Do you intend to change your behaviour?</p> <p>4. Are you optimistic about changing your behaviour?</p> <p>5. Do you have specific goals for changing your behaviour?</p> <p>6. To what extent is this behaviour accepted by your society (friends, family, employment)?</p>	Intended to support understanding of beliefs about capability, consequences, intention to perform behaviour, goals, optimism, and identity that can influence behaviour.

Table 1. Questions based on the COM-B Model - Cont'd

	<p>Automatic Motivation</p> <ol style="list-style-type: none"> 1. What are your current habits and routines related to the [behaviour]? 2. To what extent will [performing specific behaviour] make you happy or feel? 3. Are there any incentives or rewards that can motivate you to perform [specific behaviour]? <p>Additional Questions:</p> <ol style="list-style-type: none"> 1. What are your expectations from the potential mobile application? 2. What are the most important things the diabetes application should contain to improve dietary adherence? 	<p>Intended to support understanding of emotions, habits, and reinforcement factors that can influence behaviour.</p> <p>Intended to support understanding of user expectations from technology</p>
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Table 2. Questions based on the Transtheoretical Model of Change

Questions based on the Transtheoretical Model of Change		
	<p>Pre-contemplation stage</p> <p>Can you describe your current thoughts and feelings about [target behaviour]? Are you considering making any changes to address [health behaviour]?</p>	Understanding the pre-contemplation stage
	<p>Contemplation stage</p> <p>Have you noticed any benefits or drawbacks associated with [target behaviour] that are influencing your decision-making process? What specific concerns or barriers are you facing in deciding whether or not to change [target behaviour]?</p>	Understanding more about the contemplation stage
	<p>Preparation stage</p> <p>Are you actively planning or preparing to adopt [health behaviour]? Can you discuss any specific steps or strategies you have in place to facilitate behaviour change?</p>	Preparation stage
	<p>Action stage</p> <p>Have you recently started engaging in [health behaviour]? Can you discuss any challenges or successes you have experienced since initiating this behaviour change?</p>	Action stage
	<p>Maintenance stage</p> <p>How do you plan to sustain [health behaviour] over the long term? Can you discuss any ongoing efforts or resources you utilise to maintain your behaviour change?</p>	Maintaining stage
	<p>Relapse stage</p> <p>What factors or triggers led to your relapse in [target behaviour]? What plans do you have to recover from this relapse and get back on track with your behaviour change goals?</p>	Relapse Stage

Interpreting Results of Theory-Based User Research

- In case of focus groups, Braun & Clarke (2006) In the first stage of data analysis, thematic analysis using the five Braun and Clarke's the approach needs to be conducted.
 - Firstly, the data has to be familiarised with double-reading transcriptions and noting initial ideas in the data set (Familiarisation with data).
 - Secondly, initial codes need to be generated across the entire data set (Generating code).
 - Thirdly, themes need to be generated concerning the codes created before for the entire data set (Generating themes).
 - Fourth, themes must be reviewed against the data again, and improvements need to be made if needed (Reviewing themes). Lastly, each theme needs to be defined and named (Defining and naming themes). The process also included selecting data items to use as conversation extracts.
- In the second stage, themes need to be mapped onto COM-B components using the framework approach (Gale et al., 2013). It will help to organise themes according to the COM-B components. For example,
 - A theme like "Difficulty remembering to take medication" can be mapped to Psychological Capability.
 - "Lack of social support" might align with Social Opportunity.
 - "Low confidence in ability to stick with goals" can be linked to Reflective Motivation
- In case of interviews, each interview can be interpreted separately. Separate tables can be formed for each interview participant, indicating what needs to be changed (determinants of behaviour) and the stage of change.
- In the case of focus group analysis, a single composite table can be created to synthesise the data across participants. This approach allows researchers and designers to identify shared behavioural needs, barriers, motivations, and important variations among different participant types. The table can contain information such as Theme/issue, Representative quotes, COM-B Component, differences in groups (in terms of age, gender, etc), and stage of change.



Important Related References

- Atkins, L., Francis, J., Islam, R., O'Connor, D., Patey, A., Ivers, N., Foy, R., Duncan, E. M., Colquhoun, H., Grimshaw, J. M., Lawton, R., & Michie, S. (2017). A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. *Implementation Science*, 12(1), 1–18. <https://doi.org/10.1186/s13012-017-0605->
- Michie, S., Atkins, L., & West, R. (2014). *The behaviour change wheel: A guide to designing interventions*. Silverback
- Michie, S., Stralen, M. M. van, & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, 6(1), 1–12. <https://doi.org/10.1186/1748-5908-6-42>
- Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behaviour change. *American Journal of Health Promotion*, 12(1), 38–48. <https://doi.org/10.4278/0890-1171-12.1.38>
- Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M. P., Cane, J., & Wood, C. E. (2013). The behaviour change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behaviour change interventions. *Annals of Behavioural Medicine*, 46(1), 81–95. <https://doi.org/10.1007/s12160-013-9486-6>



SECTION II

THEORY ENRICHED USER PERSONA GUIDE

The regular user persona does not help estimate the possible behavioural patterns of users in the specific context of behaviour change. It provides a limited understanding of various factors: psychological, social, and environmental determinants that influence user behaviour, such as emotions, beliefs, motivation, personality, habits, norms, and other factors. Behaviour change is a long-term process consisting of different stages. Individuals can be at various stages of behaviour change (Transtheoretical Model of Change). Typical user persona descriptions do not highlight these stages of change. Regular persona templates do not focus on behaviour change goals. In designing for behaviour change, defining specific behaviour change goals could contribute to better product design.

Protocol for using the Theory – Enriched User Persona

- Cooper et al. (2014) provide detailed guidelines on developing user personas based on user research.
- A *theory-enriched user persona template* is presented below in Table 3.
- The User Segments field needs to highlight the Stages of Change. These stages are identified through the results of user research (using questions based on the Transtheoretical Model of Change). Each stage is symbolized with specific icons. Designers can use these icons to highlight the user's stage of change and may add additional textual information if needed.
- Goals related to Behaviour Change, the Target Behaviour, and the Specification of the Target Behaviour should be completed as identified in the first stage of the Behaviour Change Wheel, before conducting user research.



- A behaviour change goal is defined as the ultimate target outcome of the intervention (for example, learning how to close work-related applications on time to feel mentally and physically relaxed).
 - Identifying the target behaviour involves selecting the most appropriate behaviour to address (for example, stopping work when working hours end), from a list of potential behaviours.
 - Finally, specifying the target behaviour means clarifying what the user needs to do differently to achieve it (for example, "close all work-related devices in the evening after 6 p.m.").
-
- COM-B-based challenges and barriers related to behaviour change should explicitly highlight specific determinants that must be considered to change the intervention. This section explains what exactly must change. For example: "Psychological Capability: She needs to improve her ability to plan her schedule and incorporate regular rest times." The key results from theory-based user research will be added in this section.
 - Descriptions in fields such as Habits and Routines related to Behaviour Change, Dislikes, Concerns, and Fears (-), Likes, Interests, and Desires (+), and Motivators must be context-specific and directly related to behaviour change.
 - An example of a Persona Built on a Theory-Enriched Template is presented in Table 4



Table 3. Theory Enriched User Persona Template for DBCIs

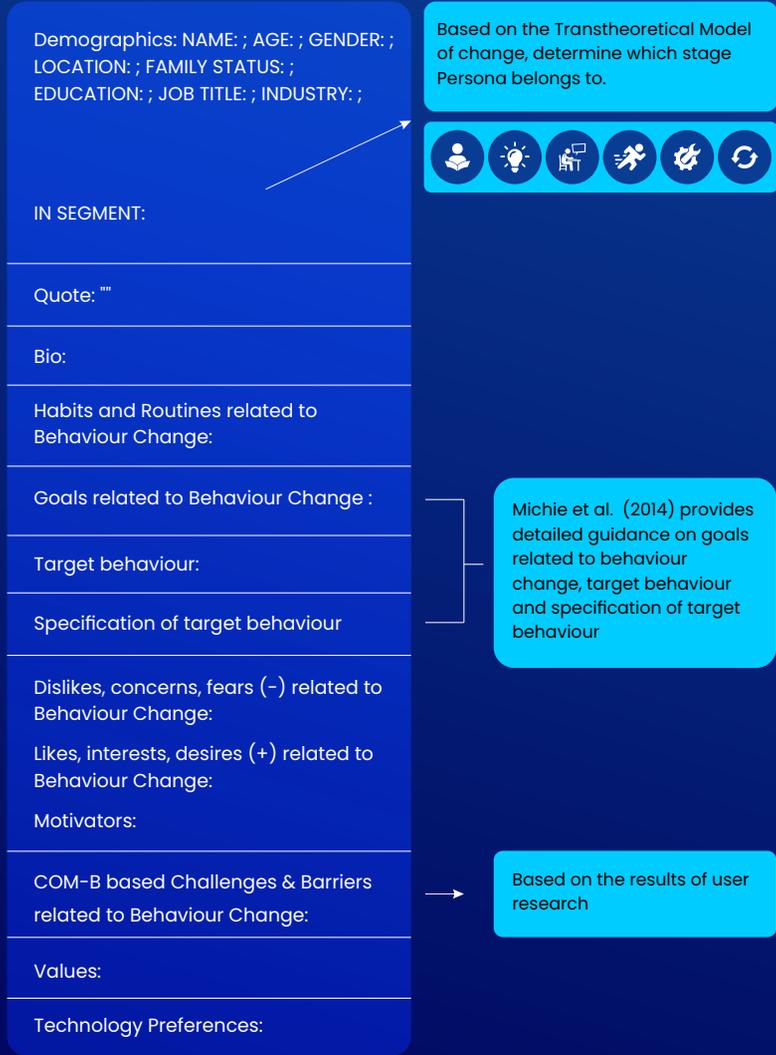


Table 4. An Example of a Persona Built on a Theory-Enriched Template



NAME: Anna;
AGE: 29;
GENDER: Female;
LOCATION: Riga, Latvia;
FAMILY STATUS: Long-term relationship without children;

DEMOGRAPHICS

EDUCATION: Master's degree;
JOB TITLE: Marketing Specialist;
INDUSTRY: IT;
IN SEGMENT: Contemplation stage

Quote: "I want to return to my normal life and enjoy time away from work."

Bio: Anna is a local from Riga. She serves individuals employed in the IT sector as a freelance marketing specialist and delivers targeted marketing services to IT companies. She has to show a constant online presence to be competitive in the market among other marketing professionals. She wants to grow in her career, but having too much work prevents her from enjoying life and spending time with her partner, who has already begun to be distant from her. Feeling burnt out lately, Anna became concerned about her mental health and realised that the first thing she needed to do was to change her habits and routine. *Being a shy person, she doesn't feel comfortable talking to her clients about the existing problem and the need for a change of her work schedule and routine.*

Habits and Routines related to Behaviour Change: Anna works more than 8 hours daily by laptop, but when she is not at the desk, continues from the smartphone. She has to show a constant online presence to be competitive in the market among other marketing professionals. She posts actively on social media because she shows examples and ideas of what her clients could do with their social media accounts. *She mainly uses WhatsApp to communicate with her clients and colleagues. She is always alert and never turns off notifications so she can read all messages immediately.*

Goals related to Behaviour Change: *Learn "how to close a laptop and stop working" on time to feel mentally and physically relaxed.*

Target behaviour: *To develop a habit of stopping working when the work hours end.*

Specification of target behaviour: *To close all work-related devices and apps, stop working after 6 p.m. and stop thinking about it, mute the WhatsApp notifications, and set up the focus mode.*

Dislikes, concerns, fears (-) related to Behaviour Change: *Anna spends too much time working and misses her personal life; she doesn't want to become distant from her partner; she is afraid of not having a planned routine and time to do everything in high quality; she feels burnout, and she is afraid of not being understood by her clients if she changes her routine and will be not available for a while. Likes, interests, desires (+) related to Behaviour Change:* She likes to spend time with her beloved ones. Anna would like to have better time-management and planning skills. **Motivators:** *Anna wants to find the right life-work balance to be productive and effective in work, but get more time for her personal life and take care of her mental health.*

COM-B based Challenges & Barriers related to Behaviour Change:

- 1. Psychological Capability:** *She needs to increase her ability to plan her schedule and regular resting time.*
- 2. Social Opportunity:** *Her clients need to understand her need to be away from work (not being reachable for a while). She feels pressure from other marketing specialists and what they set as social norms.*
- 3. Physical Opportunity:** *She does not have specific technology/tools to help her manage her routine*

Table 4. An Example of a Persona Built on a Theory-Enriched Template - Cont'd

except the laptop and smartphone.

4. Reflective Motivation: She believes that digital marketers should always be present and because of that she thinks she cannot just pause the work and focus on her personal life and quit all work-related applications.

5. Automatic Motivation: Anna always wants to check social media to respond to every message quickly, and because of that even if she closes all work-related applications, she automatically/habitually checks them every 5 minutes and cannot relax.

Values: Kindness, integrity, loyalty, hard work, relationships.

Technology Preferences: Use of laptop and phone every day - she works more than 8 hours daily with the laptop. In her work, as well as in her personal life, Anna mainly uses social media channels: LinkedIn, Instagram, Facebook, and Twitter.

Impotent Related References

- Farhat-ul-Ain, Akhmetzyanova, D., Matias, I., & Tomberg, V. (2024). Behaviour Models-Enriched User Personas for Digital Behaviour Change Interventions. Proceedings of the 17th International Conference on Pervasive Technologies Related to Assistive Environments, 140–146. <https://doi.org/10.1145/3652037.3652069>
- Cooper, A., Reimann, R., Cronin, D., Noessel, C., Csizmadi, J., & Lemoine, D. (2014). About face: The essentials of interaction design (4th ed.). John Wiley & Sons, Inc.



SECTION III

DESIGN PATTERNS FOR BEHAVIOUR CHANGE TECHNIQUES

Once user personas have been developed based on user research, the next step in the Behaviour Change Wheel (BCW) framework is to select suitable intervention functions. Intervention functions are broad categories of strategies that help facilitate behaviour change, such as education, persuasion, training, environmental restructuring, or enablement. After identifying the most relevant intervention functions for your target behaviour and user context, the next step is selecting appropriate Behaviour Change Techniques that serve each function. Behaviour change techniques are the active components of an intervention—the specific, evidence-based techniques used to bring about change (e.g., goal setting, feedback, social support, or self-monitoring). Michie et al. (2013a) developed a comprehensive taxonomy of 93 behaviour change techniques. Additionally, Michie et al. (2014) provide detailed guidance on choosing the most suitable intervention functions and behaviour change techniques.

Once behaviour change techniques have been selected, the final step is to strategise their application within Digital Behaviour Change Interventions. Behaviour Change Technique needs to be an observable, replicable, and irreducible component of an intervention; for example, the implementation of an “action planning technique” needs to indicate a plan (when, where, and how to perform a behaviour). Operationalising Behaviour change techniques within digital products require design-level translation—that is, converting abstract behavioural techniques (definition) into useful features to support the behaviour change process. This toolkit introduces design patterns, which provide ready-to-use, context-aware solutions for operationalising behaviours into digital behaviour change interventions. These patterns do not replace behavioural theory but make it accessible and actionable for designers working in digital health.

This section will provide design patterns for six commonly used Behaviour Change Techniques. Design patterns in interaction design are reusable solutions to common design problems. They provide designers with established solutions that have been proven effective in similar contexts. Based on the review (Farhat-ul-Ain et al., 2022), we have designed patterns for six of the most used Behaviour Change Techniques in digital behaviour change interventions for health.



1. Prompts and Cues
2. Social Support (unspecified)
3. Goal Setting
4. Self-Monitoring of Behaviour
5. Feedback on Behaviour
6. Instructions on How to Perform a Behaviour

Protocol for using Design Patterns

1. Once behaviour change techniques are selected, it is important to read the definitions carefully. It is important to be guided by definitions, not only by the names of behaviour change techniques.
2. Use the design patterns in this toolkit to translate selected behaviour change techniques into practical design solutions. Each pattern helps you understand Each design pattern contains the following sections mentioned in Table 5.

Table 5. Components of Design Patterns for Behaviour Change Techniques

Elements	Purpose
Pattern Name	Define the pattern name
Code/BCT name (Group) in Taxonomy	BCT's name and group are mentioned in the behaviour change technique taxonomy
Illustrative example	Screenshots of the instantiated. In our case, it presents carefully selected images of behaviour change techniques strategised in digital interventions.
What (Problem)	A short problem statement to specify the user needs for which a behaviour change technique can be used.
Use when	Conditions in which patterns can be used.
How	Represents the solution in the pattern for the behaviour change technique.
Why	Provide the design rationale for the behaviour change technique.
Design principles and theory	Establishes the link between pattern, behaviour change theory, and technique.
Behaviour change technique combinations:	Elaborate on how BCTS can be combined with other techniques.
In other collections:	Directs to similar patterns in other collections, potentially offering new insights or examples.



3. Carefully read all sections of design patterns., Use the patterns as starting points, not strict rules. You are encouraged to adapt them accordingly, as long as you maintain alignment with the theoretical definition.

Design Pattern for “Prompts and Cues Technique”

The most common behaviour change technique identified in the review was the “prompts and cues technique” (Farhat-ul-Ain et al., 2022). It is typically strategised as notifications, emails, text messages, hyperlinks, calendar events, images, and auditory signals, often synchronised with the time or location of behaviour performance. It includes employing specific stimuli to capture and direct an individual's attention towards a particular direction. This stimulus enhances an individual's capacity to retain information, focus selectively on environmental cues, and make decisions among multiple options. The design pattern for the Prompts and Cues Technique is provided in Table 6.

Table 6 . Design Pattern for Prompts and Cues Technique

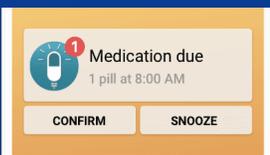
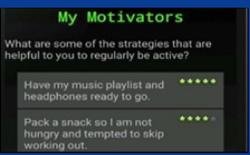
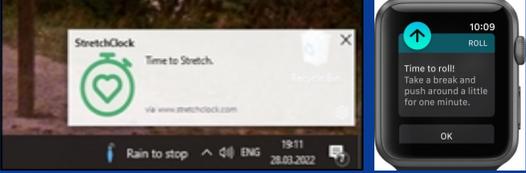
<p>Pattern Name: Reminder (alternative names: Prompt, Trigger, Cue, Call to action, Request) Code/BCT name (Group) in Taxonomy: 7.1 Prompts/Cues (Associations)</p>		
<p>Examples: AppleWatch reminder, activityApp, myTherapyApp, StretchClock</p>	 <p>A notification card with a pill icon and a red '1' badge. Text: "Medication due", "1 pill at 8:00 AM". Buttons: "CONFIRM", "SNOOZE".</p>	 <p>App interface titled "My Motivators". Question: "What are some of the strategies that are helpful to you to regularly be active?". Two items with star ratings: "Have my music playlist and headphones ready to go." (5 stars), "Pack a snack so I am not hungry and tempted to skip working out." (5 stars).</p>
 <p>Notification from StretchClock: "Time to Stretch." with a green heart icon and a link to www.stretchclock.com.</p>	 <p>Apple Watch notification: "Time to roll! Take a break and push around a little for one minute." with a "ROLL" button and "OK" button.</p>	
<p>What (Problem): Users may have trouble remembering to perform or focus on some tasks during a certain period. Users want to be reminded, informed, or motivated about the tasks or activities to form a new habit or routine or not to perform undesired ones.</p>		

Table 6 . Design Pattern for Prompts and Cues Technique – Cont'd

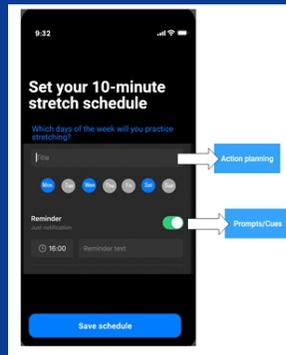
Use when: Introduce to users a prompt or cue that can be used as a reminder to act or react in the direct context. This is useful when the user needs to be reminded or motivated to take some action in a specific context (e.g., take medication, remind a doctor's appointment, take a standing pause to reduce sitting time, etc.) or rethink a planned or ongoing activity (e.g., take stairs instead of elevator, reduce speed, drink water instead of soda).

How: Use notifications or prompts to encourage specific behaviour, such as taking medication at scheduled times. These reminders can be personalised and triggered based on user-defined settings or environmental cues. Reminders could be event-based or time-based. 'Reminder' could be user-generated, system-generated or generated by another person involved (e.g., a healthcare specialist). When designing, it is important to consider that these triggers may lead to alert fatigue, habituation, or user disregard of triggers (Muench & Baumeister, 2017).

Why: If 'Reminder' matches the time and the context – then the user is more likely to be motivated and able to take a needed action or complete a task.

Design Principle and Theory: Behaviour change technique 'Prompts/Cues' as an intervention component is linked with Theoretical Domain Framework constructs 'Memory, attention and decision processes' and 'Environmental context and resources', therefore influences memory, attention, attention control, decision making, cognitive overload/tiredness (Atkins et al., 2017). Technique supports a person's ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives.

BCTs combinations: When a stimulus is linked to a specific action in an if-then plan including one or more of frequency, duration or intensity "Action planning" can be applied.



In other collections: Trigger – Fogg's Behavior change model (<https://behaviormodel.org/prompts/>), Reminding – Designing Social Interfaces: Principles, Patterns, and Practices for Improving the User Experience (Crumlish & Malone, 2015)



Design Pattern for “Social Support (Unspecified) Technique”

The second most used BCT is ‘Social support (unspecified)’, which involves providing advice, arranging, or offering support from various sources such as friends, relatives, or colleagues, as well as non-contingent praise or rewards for behaviour performance. It is commonly delivered through social networks, apps with guidance messages, text messages, testimonials, WhatsApp groups, online forums, and phone counselling. The design pattern for the “Social Support (Unspecified) Technique” is provided in Table 7.

Table 7. Social Support (Unspecified) Technique

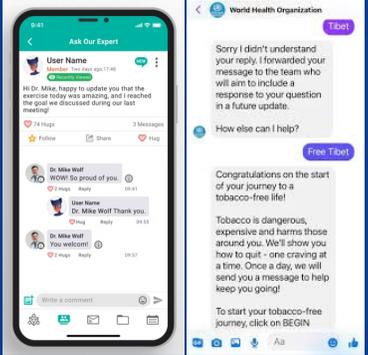
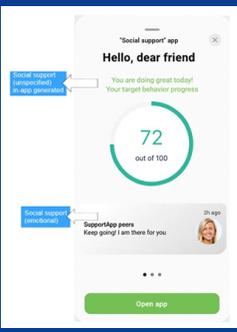
<p>Pattern Name: Social network</p> <p>Code/BCT name (Group) in Taxonomy: 3.1. Social Support (unspecified)</p> <p>Examples: Belong MS app, WHO Facebook chat-bot</p>	
<p>What (Problem): When a person tries to achieve something (target behaviour), he expects to receive various types of social support, such as praise, advice, encouragement, or guidance, through an intervention platform. When a person tries to achieve something (target behaviour), he expects to receive various types of social support, such as praise, advice, encouragement, or guidance, through an intervention platform.</p>	
<p>Use when: When designing interventions to support individuals in achieving target behaviours, it's essential to encourage interaction with the content and foster collaboration among users with mutual goals. This can be accomplished by creating engaging content that prompts participants to interact, such as liking, sharing, and commenting on posts, as demonstrated by Patrick et al. (Patrick et al., 2014) in their study on Facebook content. Additionally, providing a medium for users to form groups and support each other is crucial. For instance, Inauen et al. (Inauen et al., 2017) successfully used WhatsApp chat groups where participants encouraged each other to achieve their eating goals. 'Social Support'</p>	



Table 7. Social Support (Unspecified) Technique - Cont'd

<p>should be clearly defined in the design in terms of how it is delivered– in a group or individually, and from whom – family members, friends, specialists, and group members with the same goal; and demonstrate a connection to the target behaviour.</p>	
<p>How: An intervention platform to deliver social support related to the user's target behaviour can use various digital channels, social networks, mobile applications, text messages, testimonials, messenger groups (WhatsApp), online community forums, phone calls, and chatbots. Support providers could be – family members, friends, caregivers, group members, and the community, or the system itself (digital intervention) could offer support via images, symbols, and software-generated dialogues.</p>	
<p>Why: If a person receives 'Social support' as recognition and appreciation by others of his personal efforts and achievements, then he/she most likely will be motivated to learn and progress through their behaviour change plan.</p>	
<p>Design Principle and Theory: 'Social support' as an intervention component is linked with the Theoretical Domain Framework construct 'Social influences' – defined as a change in one's beliefs, behaviour, or attitudes caused by external pressures, whether real or imagined (Atkins et al., 2017). Three types of social support are defined: emotional, informational, and instrumental (Michie et al., 2013).</p>	
<p>BCTs combinations: To enhance the performance of a target behaviour, it is beneficial to advise on, arrange, or provide emotional, social support. This support can come from various sources, including friends, relatives, colleagues, "buddies," or staff.</p>	
<p>In other collections: Praise Design Pattern – https://ui-patterns.com/patterns/Praise Software patterns:cooperation (Oduor et al., 2014)</p>	



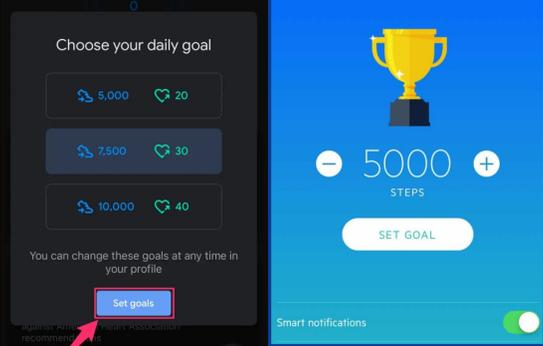
Design Pattern for “Goal Setting Technique”

The third most used BCT was the “goal-setting technique,” which helps users define their goals. It often includes features for setting specific, measurable, and time-bound objectives. It is often combined with other techniques, such as “feedback on behaviour” and “self-monitoring of behaviour,” which offer to monitor themselves and provide feedback on progress and adjustments to goals based on performance. The design pattern for the “goal-setting technique” is provided in Table 9.

Table 8. Design Pattern for Goal Setting (behaviour) Technique

Pattern Name: Goal Scheduler
Code/BCT name (Group) in Taxonomy: Goal setting (behaviour) (Goals and planning)

Examples: Google Fit app, MoveSum app



What (Problem): Digitally supported interventions enable users to establish behaviour-oriented goals tailored to their intentions within the intervention platform. Users have the capability to define specific behavioural objectives aligned with their desired outcomes within the digital intervention setting. This feature empowers users to personalise their goals based on individual preferences and motivations, fostering engagement and facilitating targeted behaviour change efforts.

Use when: Pattern ‘Goal setting’ helps users to achieve specific behavioural changes or desired outcomes. Useful for establishing habitual behaviours that contribute to achieving desired outcomes effectively and sustainably. In interventions, patterns can be set by either the target user themselves or by experts designing goals on behalf of the target user. Collaborative approaches, where users receive expert guidance in selecting appropriate goals, can ensure that goals are tailored to individual needs and capabilities. This method promotes personalised goal setting that aligns with individual circumstances, enhancing the likelihood of successful behaviour change.



Table 8. Design Pattern for Goal Setting (behaviour) Technique - Cont'd

How: When setting goals within an intervention platform, it is crucial to ensure they are specific, measurable, realistic, achievable, time-based, and directly relevant to the target behaviour. Using in-app calculators and virtual agents and synchronising with popular calendar platforms like Google Calendar or iCal can enhance goal management and tracking. This diversified approach supports structured and systematic goal setting, thereby increasing the efficacy of behaviour change interventions.

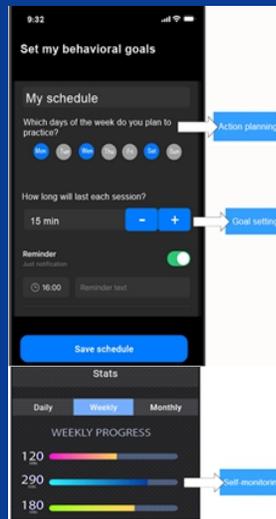
Why: Goals help individuals plan and motivate their intention to achieve desired outcomes. They focus attention away from irrelevant tasks and towards behaviours that are relevant to achieving the goal.

Design Principle and Theory: Behaviour change technique 'Goal setting' refers to Theoretical Domain Framework constructs such as 'Intention' and 'Goals'. Technique supports a person's ability to decide consciously to perform a behaviour or a resolve to act in a certain way and provides the mental representations of outcomes, or end states that an individual wants to achieve (Atkins et al., 2017).

BCT combinations: The Behaviour Change Technique (BCT) taxonomy suggests that goal setting within interventions is more effective when accompanied by 'Action planning' and 'Self-monitoring of behaviour.'

"Action planning" involves specifying details like frequency, duration, or intensity of desired behaviour, while "Self-monitoring" means tracking progress towards goals. Integrating detailed behavioural planning and ongoing monitoring significantly enhances intervention effectiveness.

Self-monitoring can be facilitated through self-tracking devices, wearable technology, or in-app sensors, providing feedback to users on their progress. This alignment with evidence-based strategies optimises the impact of behaviour change interventions on user outcomes (Michie et al., 2013)



In other collections: Reduction & Tunneling – Fogg's Persuasive Design Principles (Fogg, 2003), Goal-Gradient Effect – <https://ui-patterns.com/patterns/Completion>



Design Pattern for “Self-Monitoring of Behaviour Technique”

The fourth most used BCT was the “goal-setting technique”, which helps users individuals observe and document their actions as part of an effort to modify behaviour. It involves the systematic collection of pertinent health information, exemplified by participants modifying their smoking tracker based on daily cigarette consumption (Garrison et al., 2020; Lee et al., 2021). The design pattern for “self-monitoring of behaviour” is provided in Table 9.

Table 9. Design Pattern for Self-monitoring of Behaviour

Pattern Name: Behavioural Tracker
Code/BCT name (Group) in Taxonomy: 2.3 Self-monitoring of behaviour (Feedback and monitoring)
<p>Examples: Kwit app for smoking cessation</p>
<p>What (Problem): Individuals frequently encounter challenges in maintaining awareness of their actions and progress towards their desired health objectives. Adopting the practice of “self-monitoring of behaviour,” which involves actively tracking and documenting activities relevant to health goals, can facilitate informed decision-making and facilitate positive behavioural changes. Tang et al. (Tang et al., 2015) mentioned that self-monitoring enhances users’ self-awareness regarding their actions and motivations, motivating them to reconsider their habits and intentions towards change.</p>
<p>Use when: It is useful for systematically tracking and visually representing key parameters of behaviour. It is especially beneficial for individuals managing chronic conditions like diabetes or obesity, or those aiming to adopt healthier habits. Additionally, it helps transform new habits, such as improving diet and reducing sedentary screen time, into automated routines, reducing the need for extensive self-regulation (Pellegrini et al., 2014). As self-regulation improves, individuals can better prioritise physical activity, integrate new habits, and pursue additional goals, enhancing behaviour change efforts.</p>



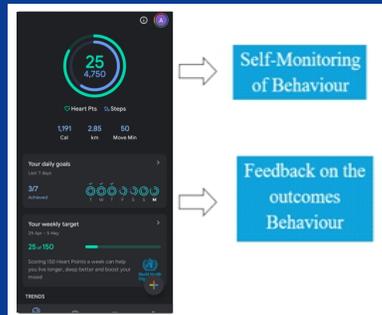
Table 9. Design Pattern for Self-monitoring of Behaviour - Cont'd

How: Include an in-app journaling feature to help users document their behaviour and implement real-time behaviour monitoring options (for example, wearable technology) (Garrison et al., 2020). Simplify the self-monitoring methods to reduce recording frequency to enhance user adherence (Goodman et al., 2016).

Why: Self-monitoring increases awareness of behaviour and facilitates deliberate decision-making. Self-monitoring is a reliable method for sustaining user engagement and adherence to goals (Tang et al., 2015).

Design Principle and Theory: 'Self-monitoring' is associated with the theoretical construct 'behaviour regulation' in the Theoretical Domain Framework. It involves efforts to control or alter objectively observed or measured behaviour (Atkins et al., 2017).

BCT combinations: The Behaviour Change Technique (BCT) taxonomy suggests that goal setting within interventions is more effective when accompanied by "Action planning" and "Self-monitoring of behaviour." "Action planning" involves specifying details like frequency, duration, or intensity of desired behaviour, while "Self-monitoring" means tracking progress towards goals. Integrating detailed behavioural planning and ongoing monitoring significantly enhances intervention effectiveness. Self-monitoring can be facilitated through self-tracking devices, wearable technology, or in-app sensors, providing feedback to users on their progress. This alignment with evidence-based strategies optimises the impact of behaviour change interventions on user outcomes (Michie et al., 2013)



In Other Collection: Self-monitoring - <https://ui-patterns.com/patterns/self-monitoring>. Self-monitoring - Persuasive Systems Design: Key Issues, Process Model, and System Features (Oinas-Kukkonen & Harjumaa, 2009).

Design Pattern for “Instructions on How to Perform a Behaviour Technique”

The fifth most used BCT was “instructions on how to perform a behaviour,” which involves offering advice and instruction on behaviour execution, often including skills training. This technique equips individuals with the expertise and skills necessary to achieve desired objectives. The design pattern for “instructions on how to perform behaviour” is provided in Table 10.

Table 10. Design Pattern for Instructions on How to Perform Behaviour Technique

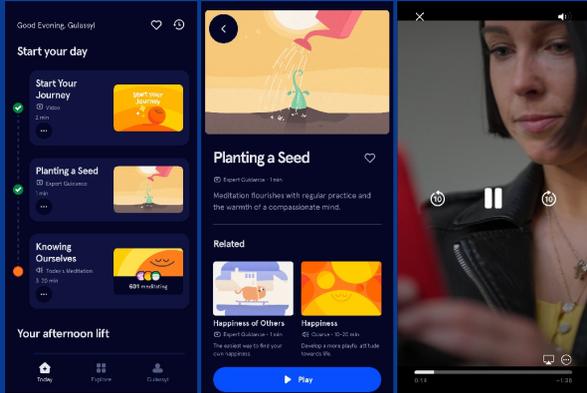
<p>Pattern Name: Guided task assistance</p> <p>Code/BCT name (Group) in Taxonomy: 4.1. Instruction on how to perform the behaviour (Shaping knowledge)</p> <p>Examples: Headspace</p> <p>Headspace provides instructions from the first interaction with the app, akin to a roadmap that offers its users dynamic, step-by-step guidance for meditation</p>	
<p>What (Problem): Key challenges individuals face when adopting desired behaviours include the lack of knowledge, misconceptions, and behaviour complexity.</p>	
<p>Use when: Crucial in guiding individuals on specific behaviours, particularly when users lack knowledge or expertise in certain areas. The instructional components in mobile applications are important in assisting users in implementing behaviours effectively (Vasilio & Byrne, 2020). Providing relevant information on behaviours enhances user knowledge and reduces frustrations associated with behaviour adoption.</p>	



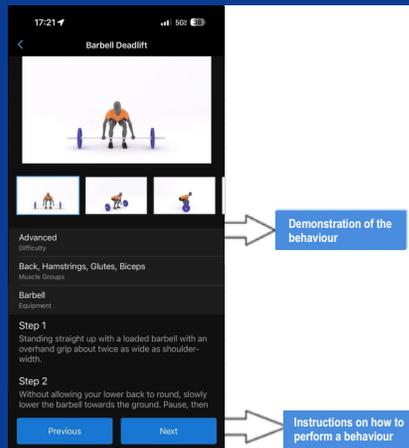
Table 10. Design Pattern for Instructions on How to Perform Behaviour Technique - Cont'd

How: Offer interactive or visual guides (e.g., animations, videos, or text) that explain each step in performing the behaviour, implement in-app tutorials that can be revisited anytime, and provide ongoing reminders with clear, actionable instructions and animated presentations to help users learn new knowledge and behaviour. This pattern enhances the likelihood of successful behaviour change by offering clear guidance, breaking tasks into manageable steps, accelerating skill acquisition, and providing solutions to obstacles (Buman et al., 2016; Szabó et al., 2015; Vasilidou & Byrne, 2020). Enhance user engagement with infographics and user stories to simplify instructions and improve comprehension (Fulton et al., 2016).

Why: Pattern empowers users with essential knowledge on the significance of specific actions and how to integrate them effectively into daily life, facilitating informed decision-making and progress towards goals. Pattern offers simple guidance to overcome difficulties and barriers and enhances users' self-awareness. By providing tips, strategies, and suggestions, these instructions help users navigate obstacles and stay on course towards achieving their goals. These integrated strategies create a comprehensive, user-centric approach to instruction design, promoting successful intervention adherence.

Design Principle and Theory: "Instructions on how to perform a behaviour" is linked to the theoretical concept of "knowledge" within the Theoretical Domain framework. This technique encompasses both general knowledge, including awareness of the condition or scientific reasoning, and procedural knowledge (Atkins et al., 2017). s efforts to control or alter objectively observed or measured behaviour (Atkins et al., 2017).

BCT combinations: To enhance this pattern, combined with BCT under code 8.1, "Behavioral practice/rehearsal," repeated practice is suggested to improve skills. And BCT under code 6.1, "Demonstration of the behaviour," involves learners receiving detailed demonstrations and then practising by observing and replicating what they saw, which can be effective (Michie et al., 2013)



In Other Collection: Wizard - <https://ui-patterns.com/patterns/Wizard>



Design Pattern “Feedback on Behaviour Technique”

The sixth most used BCT was the “feedback on behaviour technique,” which provides evaluative feedback on behaviour performance, considering factors like its form, frequency, duration, and intensity. It is often combined with goal-setting and reward techniques. The design pattern for feedback on behaviour” is provided in Table 11.

Table 11. Design Pattern for Feedback on Behaviour Technique

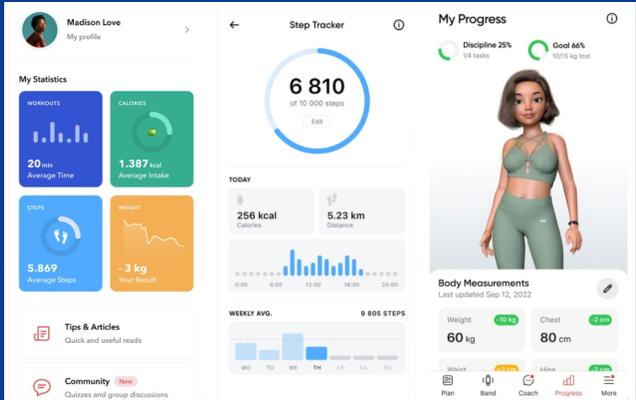
<p>Pattern Name: Progress Feedback Code/BCT name (Group) in Taxonomy: 2.2 Feedback on behaviour (Feedback and monitoring)</p>
<p>Examples: BetterMe health coaching app</p>  <p>The screenshot displays a mobile app interface for a health coaching app. It features a profile section for 'Madison Love' with statistics for workouts (20 min), calories (1,387 kcal), steps (5,869), and weight loss (-3 kg). A central 'Step Tracker' shows 6,810 steps out of a 10,000 goal. The 'My Progress' section includes a 3D avatar, discipline and goal progress bars, and body measurements (Weight: 60 kg, Chest: 80 cm). A weekly average bar chart shows 9,605 steps.</p>
<p>What (Problem): The pattern “Feedback on behaviour” in apps addresses the problems of improving user engagement, motivating desired actions, and facilitating behaviour change by providing users with real-time insights, guidance, and accountability. This ultimately leads to more informed decision-making and positive outcomes.</p>
<p>Use when: Use when: Useful when individuals need to be more aware of their behaviours, enabling them to track progress, identify patterns, and make necessary adjustments. To help individuals gauge their progress, celebrate successes, and address behaviours that need improvement. To reinforce desired behaviours and correct undesired ones. To encourage healthier choices and lifestyle changes. To help individuals understand areas of strength and areas needing development, fostering continuous improvement.</p>



Table 11. Design Pattern for Feedback on Behaviour Technique – Cont'd

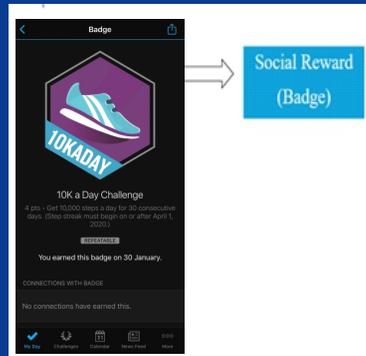
How: Using visual representations, behaviour-specific feedback messages, timely feedback delivery, convenient access to feedback, personalised feedback on individual data, and regular summaries can be used to strategise “Feedback on behaviour” (Bell et al., 2018; Buman et al., 2016; Nibbeling et al., 2021; Patrick et al., 2014; Stacey et al., 2021). Providing users with control over feedback types and also helping users understand feedback.

Why: Feedback on behaviour is crucial because it enables individuals to assess their actions about their goals and objectives, facilitating self-management and behavioural control. By receiving feedback and reviewing goals based on that feedback, individuals can make informed adjustments to their behaviours, aligning them more effectively with desired outcomes.

Design Principle and Theory: “Feedback on behaviour” is linked to the theoretical concept of “behavioural regulation” within the Theoretical Domain Framework. It entails systematic efforts focused on controlling or altering objectively observable and measurable behaviours (Atkins et al., 2017).

BCT combinations: The pattern can be combined with “Monitoring of behaviour by others without feedback” (BCT code 2.1), which involves observing an individual’s behaviour without providing explicit feedback, such as when a fitness coach tracks activity levels but does not comment on performance.

Conversely, “Social reward” (BCT code 10.4) involves giving praise or recognition for behaviour, such as a fitness app awarding badges or providing encouragement when a user achieves their daily step goal (Michie et al., 2013).



In Other Collection: Completeness Meter - <https://ui-patterns.com/patterns/CompletenessMeterPraise/Reward> - Persuasive Systems Design: Key Issues, Process Model, and System Features (Oinas-Kukkonen & Harjumaa, 2009).



Important Related References

Farhat-ul-Ain, Popovič, O., & Tomberg, V. (2022). Mapping Behavior Change Wheel Techniques to Digital Behavior Change Interventions: Review. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13304 LNCS, 277–295. https://doi.org/10.1007/978-3-031-05412-9_20/COVER



APPENDIX 2

	QUOTE	
	BIO (Demographics & Professional)	
NAME:	MOTIVATORS:	
	Dislikes, concerns & fears (-)	Likes, interests & desires (+)
AGE:	•	•
GENDER:	GOALS/NEEDS	
LOCATION:	HABITS AND ROUTINES	
FAMILY STATUS:	CHALLENGES AND BARRIERS	
EDUCATION:	VALUES	
JOB TITLE:	PERSONALITY ADJECTIVES:	
INDUSTRY:		
IN SEGMENT:	ADDITIONAL FIELDS:	

KOKKUVÕTE

Digitaalsed käitumise muutmise sekkumised (inglise keeles Digital Behavior Change Intervention, ehk DBCI) on saanud olulisteks vahenditeks tervislike harjumuste edendamisel ja säilitamisel. DBCI disain on interdistsiplinaarne, kaasates nii sekkumise-kui ka interaktsioonidisaini. sekkumise disain sisaldab tõenduspõhiseid teooriaid, mis toovad esile erinevad psühholoogilised, sotsiaalsed ja keskkondlikud tegurid, mis mõjutavad käitumist, ning sisaldavad käitumise muutmise tehnikaid, mis hõlbustavad käitumise muutmist. Interaktsioonidisain keskendub digitaalsete toodete interaktiivsele käitumisele, rakendades selliseid lähenemisi, nagu kasutajakeskne disain ja eesmärgipõhine disain, mis pakuvad struktureeritud protsesse interaktsioonimeetodite (nt intervjuud, fookusgrupid ja kasutajapersoonad) loogilise järjestuna, et mõista kasutajate vajadusi, eesmäärke ja motivatsioone ning kasutada neid digitaalsete toodete kujundamisel. Kuigi interdistsiplinaarsust tunnistatakse, on käitumisteooriate rakendamine interaktsioonidisaini praktikas DBCIde arendamisel endiselt piiratud. Interaktsioonidisainerid valdavad mitmesuguseid interaktsioonidisaini meetodeid, nagu intervjuud, fookusgrupid ja persoonad, kuid tavapärased tööriistad, mis neid meetodeid toetavad, ei ole piisavalt kohandatud käitumise muutmise seotud teadmiste kogumiseks ja rakendamiseks. Seetõttu on interaktsioonidisaineritel raskusi käitumise muutmise seotud konkreetsete vajaduste, takistuste ja soodustavate tegurite tuvastamisel, mis teeb disainiga seotud otsuste langetamise keerulisemaks. Lisaks puudub struktureeritud juhendmaterjal selle kohta, kuidas lõimida käitumisteooriatest saadud teadmisi disainiprotsessi. Seetõttu on vaja lähenemist, mis aitaks interaktsioonidisaineritel paremini kasutada käitumise muutmise teooriatest saadud teadmisi.

Väljakutsete ületamiseks on selle uurimistöö peamiseks eesmärkideks täiustada ja rikastada olemasolevaid tööriistu, mis toetavad interaktsioonidisaini meetodeid DBCIde kujundamisel tervisevaldkonnas, lõimides käitumise muutmise teooriaid interaktsioonidisaini tööriistadesse. Selle eesmärgi saavutamiseks töötati välja digitaalsete käitumise muutmise (inglise keeles, Digital Health Behavior Change, ehk DHBC) tööriistakast interaktsioonidisaineritele, mis toetab käitumise muutmise teooriatest saadud teadmiste lõimimist disainiprotsessi ning mille tulemusel loodi neli panust. Uurimistöös kasutati nii Research for Design kui ka Research through Design lähenemisi, kombineerituna iteratiivse ja refleksiivse protsessiga, et arendada praktilisi tööriistu, mis aitavad disaineritel lõimida käitumise muutmise teooriaid DBCIde disaini.

Lõputöö esimene panus hõlmab teooriaga rikastatud kasutajauuringute teema juhendit teoriapõhiste intervjuude/fookusgruppide toetamiseks. Juhendi koostamiseks valiti COM-B mudel (võimekus, võimalus, motivatsioon – käitumine) ja transteoreetiline muutumismudel. Eesmärk on pakkuda disaineritele üldine teema juhend, mida saab hõlpsasti kohandada ja kasutada erinevates tervise rakendusvaldkondades. Kavandatud teooriaga rikastatud kasutajauuringute

juhendi malli hinnati juhtumiuuringu meetodil. Tulemused tõid esile laste erinevad käitumise muutmisega seotud vajadused ning vanusega seotud erinevused laste oskustes, iseseisvuses ja motivatsioonis diabeedi juhtimisel, rõhutades tööriistakasti kasulikkust käitumise muutmise vajaduste tuvastamisel.

Teine panus hõlmab teooriaga rikastatud kasutajapersonade juhendit ja malli. See sisaldas konkreetseid osad, mis olid seotud käitumise muutmise eesmärkidega, COM-B mudelil põhinevate takistuste ja väljakutsetega ning kasutajasegmentidega muutuseetappide alusel. Kavandatud juhendit hindasid eksperdid. Kõik eksperdid toetasid käitumise muutmisega seotud osade lisamist tavapärasele persoonamallile, pidades seda kasulikuks, ning andsid soovitusi täienduste tegemiseks.

Kolmas panus sisaldab ekspertide välja töötatud ja hinnatud kuue populaarse käitumise muutmise tehnika disainimustreid. Eksperdid leidsid, et disainimustrite kirjeldused ja näited olid kasulikud, selged ja arusaadavad. Lõpptulemuseks saadud põhjalik DHBC tööriistakast sisaldab kõiki kavandatud tööriistade lõppversioone koos vajalike juhistega disaineritele. Käesoleva töö eesmärk on aidata meeskondades töötavaid interaktsioonidisainereid, kellel ei pruugi ligipääsu olla käitumiseexpertidele või kes soovivad nendega suhtlemist ja koostööd parandada. Tulevikutöö hõlmab tööriistade edasist täiustamist, tuginedes ekspertide tagasiside põhjal tuvastatud parandusvaldkondadele ning suurendades nende rakendatavust erinevates disainikontekstides.

Varustades interaktsioonidisainereid tööriistadega, mis võimaldavad luua paremaid DBCId, võib paraneda ka üksikisikute heaolu ja väheneda surve tervishoiusüsteemidele, andes seeläbi panuse nii disainipraktikasse kui ka laiemasse ühiskondlikku mõjusse.

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TALLINNA ÜLIKOOL
LOODUSTEADUSTE DISSERTATSIOONID

TALLINN UNIVERSITY
DISSERTATIONS ON NATURAL SCIENCES

1. KAI KÜNNIS. Spatio-Temporal Regulation of Bacterioplankton on Distribution and Composition in Marine Habitats. Tallinn: University Press, 1999. 175 p. Tallinn University. Dissertations on Natural Sciences, 1. ISSN 1406-4383. ISBN 9985-58-083-4.
2. EDGAR KAROFELD. Formation and Development of Microtopography on Estonian Raised Bogs. Tallinn: University Press, 1999. 133 p. Tallinn University. Dissertations on Natural Sciences, 2. ISSN 1406-4383. ISBN 9985-58-114-8.
3. AINA LEEBEN. Fluorescent Analysis of Pigment Composition of Phytoplankton. Tallinn: University Press, 2000. 224 p. Tallinn University. Dissertations on Natural Sciences, 3. ISSN 1406-4383. ISBN 9985-58-132-6.
4. TIIU ALLIKSAAR. Spatial and Temporal Variability of the Distribution of Spherical Fly-Ash Particles in Sediments in Estonia. Tallinn: University Press, 2000. 224 p. Tallinn University. Dissertations on Natural Sciences, 4. ISSN 1406-4383. ISBN 9985-58-150-4.
5. SVETLANA JEVREJEVA. Influence of Large-Scale Atmospheric Patterns on the Ice Conditions in the Baltic Sea. Tallinn: University Press, 2002. 134 p. Tallinn University. Dissertations on Natural Sciences, 5. ISSN 1406-4383. ISBN 9985-58-218-7.
6. AIN LANKOV. Feeding Ecology of the Pelagic Fishes in the Northeastern Baltic Sea in 1980–1990-s. Tallinn: University Press, 2002. 192 p. Tallinn University. Dissertations on Natural Sciences, 6. ISSN 1406-4383. ISBN 9985-58-220-9.
7. ILMAR KOTTA. Population Ecology of Mysids in the Gulf of Riga. Tallinn: University Press, 2003. 136 p. Tallinn University. Dissertations on Natural Sciences, 7. ISSN 1406-4383. ISBN 9985-58-252-7.
8. ANDRES KRATOVITS. Driving Forces of the Formation of Estonia's International Environmental Cooperation in the 1990-s. Tallinn: University Press, 2003. 106 p. Tallinn University. Dissertations on Natural Sciences, 8. ISSN 1406-4383. ISBN 9985-58-282-9.
9. REIMO RIVIS. Shoreline Dynamics in Estonia Associated with Climate Change. Tallinn: University Press, 2005. 119 p. Tallinn University. Dissertations on Natural Sciences, 9. ISSN 1406-4383. ISBN 9985-58-360-4.
10. TIINA PAALME. Nuisance Brown Macroalga *Pilayella Littoralis*: Primary Production, Decomposition and Formation of Drifting Algal Mats. Tallinn: University Press, 2005. 104 p. Tallinn University. Dissertations on Natural Sciences, 10. ISSN 1406-4383. ISBN 9985-58-375-2.
11. JAANUS TERASMAA. Seston Fluxes and Sedimentation Dynamics in Small Estonian Lakes. Tallinn: University Press, 2005. 200 p. Tallinn University. Dissertations on Natural Sciences, 11. ISSN 1406-4383. ISBN 9985-58-382-5.
12. MIHKEL KANGUR. Disturbances and Vegetation Patchiness Reflected in Pollen and Charcoal Profiles from Lacustrine Sediments. Tallinn: University Press, 2005. 135 p.

- Tallinn University. Dissertations on Natural Sciences, 12. ISSN 1406-4383. ISBN 9985-58-384-1.
13. AKO SAUGA. The Influence of Environmental Fluctuations on the Dynamics of Non-linear Systems. Tallinn: University Press, 2006. 96 p. Tallinn University. Dissertations on Natural Sciences, 13. ISSN 1736-3616. ISBN 9985-58-425-2.
 14. TENNO DREVS. Ecology of Flounder, *Platichthys Flesus Trachurus* (Duncker) in the Eastern Baltic Sea. Tallinn: University Press, 2006. 128 p. Tallinn University. Dissertations on Natural Sciences, 14. ISSN 1736-3616. ISBN 978-9985-58-445-3. ISBN 9985-58-445-7.
 15. TIIT MARAN. Conservation Biology of the European Mink, (Linnaeus 1761): Decline and Causes of Extinction. Tallinn: University Press, 2007. 194 p. Tallinn University. Dissertations on Natural Sciences, 15. ISSN 1736-3616. ISBN 978-9985-58-467-5.
 16. ANGELIKA PORTSMUTH. Ecophysiological Mechanisms of Forest Plant Growth and Biomass Distribution. Tallinn: University Press, 2008. 189 p. Tallinn University. Dissertations on Natural Sciences, 16. ISSN 1736-3616. ISBN 978-9985-58-537-5.
 17. HANNES TÕNISSON. Development of Spits on Gravel Beach Type in Changing Storminess and Sea Level Conditions. Tallinn: University Press, 2008. 111 p. Tallinn University. Dissertations on Natural Sciences, 16. ISSN 1736-3616. ISBN 978-9985-58-537-5.
 18. MARIAN PADUCH. The Diagnostics Problems at Implementation of Plasma Focus Tehnique in Material and Enviromental Sciences. Tallinn: University Press, 2009. 143 p. Tallinn University. Dissertations on Natural Sciences, 18. ISSN 1736-3616. ISBN 978-9985-58-635-8.
 19. RANDO TUVIKENE. Functional Dependencies of the Chemical Compositon and Structures in the Baltic Sea Algal Communities. Tallinn: University Press, 2009. 148 p. Tallinn University. Dissertations on Natural Sciences, 19. ISSN 1736-3616. ISBN 978-9985-58-646-4.
 20. ERKKI SOIKA. Constructive Role of Enviromental Noise in Ecological Modelsystems. Tallinn: Tallinn University, 2010. 166 p. Tallinn University. Dissertations on Natural Sciences, 20. ISSN 1736-3616. ISBN 978-9949-463-06-0.
 21. TIIT VAASMA. Grain-size Analysis of Lake Sediments: Research Methods and Applications. Tallinn: Tallinn University, 2010. 130 p. Tallinn University. Dissertations on Natural Sciences, 21. ISSN 1736-3616. ISBN 978-9949-463-12-1.
 22. JAANIS PRIIMETS. Diffusion Paths in Single-Phase Ternary Metal Systems. Tallinn: Tallinn University, 2010. 106 p. Tallinn University. Dissertations on Natural Sciences, 22. ISSN 1736-3616. ISBN 978-9949-463-28-2.
 23. KAJA PETERSON. Drivers of Effectiveness of Enviromental Assessmen. Tallinn: Tallinn University, 2010. 123p. Tallinn University. Dissertations on Natural Sciences, 23. ISSN 1736-3616. ISBN 978-9949-463-65-7.
 24. LIISA PUUSEPP. Spatio-Temporal Variability of Diatom Assemblages in Lake Sediments. Tallinn: Tallinn University. 2011. 142 p. Dissertations on Natural Sciences, 24. ISSN 1736-3616. ISBN 978-9949-463-72-5.

25. EGERT VANDEL. Formation of Plant Macrofossil Records in Lacustrine Sediments of the Baltic Region and Their Palaeolimnological Implications. Tallinn: Tallinn University. 2011. 116 p. Dissertations on Natural Sciences, 25. ISSN 1736-3616. ISBN 978-9985-58-720-1.
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