Leveraging Implementation Science in Human-Centred Design for Digital Health

Alex Waddell
alex.waddell@monash.edu
Action Lab, Monash University
Clayton, Victoria, Australia

Joshua Paolo Seguin
joshua.seguin@monash.edu
Action Lab, Monash University
Clayton, Victoria, Australia

Ling Wu
ling.wu@monash.edu
Action Lab, Monash University
Clayton, Victoria, Australia

Peta Stragalinos
Peta.stragalinos@monash.edu
Eastern Health Clinical School, Monash University
Clinical and Social Research, Turning Point, Victoria, Australia

Joe Wherton
joseph.wherton@phc.ox.ac.uk
Nuffield Department of Primary Care Health Sciences, Oxford University
Oxford, United Kingdom

Jessica L. Watterson
jessica.watterson@monash.edu
Action Lab, Monash University
Clayton, Victoria, Australia
Jeffrey Cheah School of Medicine and Health Sciences, Monash University
Malaysia, Malaysia

Christopher Owen Prawira
chris.prawira@monash.edu
Action Lab, Monash University
Clayton, Victoria, Australia

Patrick Olivier
patrick.olivier@monash.edu
Action Lab, Monash University
Clayton, Victoria, Australia

Victoria Manning
victoria.manning@monash.edu
Eastern Health Clinical School, Monash University, Victoria, Australia

Dan Lubman
dan.lubman@monash.edu
Eastern Health Clinical School, Monash University
Victoria, Australia

Jasmin Grigg
jasmin.grigg@monash.edu
Eastern Health Clinical School, Monash University
Clinical and Social Research, Turning Point, Victoria, Australia

ABSTRACT

There are increasing concerns that digital interventions in healthcare settings could be better designed for scalable and sustained use. Implementation science is the scientific study of how to embed evidence-based interventions in practice. Calls to integrate implementation science and Human-Centred Design methods have focused on integrating design methods within implementation science processes. By contrast, we present a novel approach to integrating implementation science within Human-Centred Design for digital health interventions. Our approach leverages the sociotechnical Nonadoption, abandonment, scale-up, spread, and sustainability (NASSS) framework within the distinct phases of the Double Diamond process. To illustrate our proposal we demonstrate its application in the redesign of a brief health promotion intervention to reduce the risk of alcohol-attributable breast cancer in women attending routine mammography. We discuss reflections on the approach and implications for future research that targets implementation within design.

CHI '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0330-0/24/05
https://doi.org/10.1145/3613904.3642161

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; • **Applied computing** → **Life and medical sciences**.

KEYWORDS

Implementation Science, Digital Health Infrastructure, Intervention Design, Health

ACM Reference Format:
Alex Waddell, Joshua Paolo Seguin, Ling Wu, Peta Stragalinos, Joe Wherton, Jessica L. Watterson, Christopher Owen Prawira, Patrick Olivier, Victoria Manning, Dan Lubman, and Jasmin Grigg. 2024. Leveraging Implementation Science in Human-Centred Design for Digital Health. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24), May 11–16, 2024, Honolulu, HI, USA.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3613904.3642161

1 INTRODUCTION

Digital infrastructure is increasingly used in health and healthcare settings to increase access, and optimise healthcare experiences and outcomes [43, 58, 74]. While it is clear that Human-Computer Interaction (HCI) has a role to play, HCI has a multifaceted relationship with digital health. For example, HCI researchers are the source of innovation in diagnosis technologies [83], understanding of users (including patients [53], healthcare professionals [97] and carers [50] etc.), new service models, design and evaluation methods [46, 88]. However, as is common of research in a specific discipline,

most health-focused HCI research is positioned (i.e, framed, executed and reported) in terms of the contribution it makes to HCI as a discipline. At the same time, there is both a growing need for understandings from HCI to have a more direct impact on digital health, increasing concerns that digital interventions are not designed for real-world implementation or have not considered the complexities of implementation during the design phase, leading to research waste [52, 59].

In this paper we propose and explore an approach for design practitioners in HCI to engage more directly in real-world digital health innovation through a pragmatic approach that integrates implementation science in the design, iteration and refinement of digital health interventions for clinical trials and long-term adoption. Implementation science is the scientific study of what works to embed evidence-based interventions in practice [26]. However, implementation science often focuses on the determinants of implementation of specific interventions and implementation strategies, rather than the design of the intervention and its strategies [69]. Furthermore, implementation science faces an ongoing tension between fidelity of evidence-based programs and the need for adaptation within different contexts [95]. As reported by others, HCI methods have clear value for implementation science especially in user-centredness and iterative approaches [25, 54]. Likewise, designing with implementation science in mind has potential benefits for the uptake, scale and sustainability of evidence-based digital interventions.

Implementation science is gaining traction within the HCI community. CHI 2023 saw the first workshop devoted to bridging implementation science and HCI [55]. The workshop, facilitated by Lyon et al., (2023), focused on describing the similarities and differences between the two fields while promoting collaboration. Whilst this forum prompted useful discussion on the subject, these remained broadly abstract, lacking explicit worked examples as to how implementation science and HCI methods may come together [55]. Research to date has provided examples of how to integrate HCI (specifically user- and human-centred design) into implementation science methods and tends to appear in health-specific journals [16, 25, 25, 65]. HCI has not studied many examples of integrating implementation science into HCI, as demonstrated by a search of "implementation science" in the ACM Digital Library, which returns only 61 publications. This paper aims to address the current gap in literature by providing a practical approach for HCI designers to use implementation science in practice. We contribute to both HCI and implementation science by providing a novel approach, which foregrounds essential implementation domains throughout the design process.

We provide a description of our proposal to bridge the two fields by integrating human-centred design (using the Double Diamond process [20]) and Nonadoption, abandonment, scale-up, spread, and sustainability (NASSS) implementation science framework [35]. We provide an example use of our proposed approach and present a provisional set of reflections on its utility, challenges and opportunity for future research through a case study. The case study is the redesign of a digital health promotion intervention targeting women attending breast screening services, with the goal of reducing alcohol-attributable breast cancer risk. Although the primary focus of the paper is not to present empirical results of the case study, we discuss specific findings that provide context to underlying processes.

Our contribution to HCI is a proposal of a clear approach to integrating implementation science within the human-centred design of a specific digital health intervention that will be implemented within a health service. Our aim is to leverage the benefits of implementation science to maximise its effectiveness, implementability, and long-term use beyond the research phase. While others examine the application of human-centred design and user-centred design within implementation science, this work novel in its exploration of the integration of implementation science concepts within human-centred design for health technology [16, 25, 25, 65]. Our specific case study, that we use to illustrate the proposed approach, will also be of relevance to researchers and practitioners as an exemplar of implementation-aware design of a health intervention aimed at changing the behaviour of a large and diverse group with different needs.

2 BACKGROUND

2.1 Current Gaps in the Design of Digital Health Interventions

There has been a rapid increase in the number of digital health interventions in recent years [49, 90]. By digital health interventions, we refer to those interventions that are evidence-based and aim to be used in practice in health organisations or systems. Accelerated through COVID-19, these interventions promise to increase reach, equality, and use of evidence-based information for the public good compared to their non-digital counterparts [51]. However, the promises are often not delivered due to small scale projects or pilot studies in digital health failing to achieve real-world implementation, or implementation success cases not comprehensively reported in the literature [73].

The field of HCI has contributed significantly to the design and development of many digital health interventions. These innovations have often been developed with deep engagement of end-users or communities - a clear strength of the field of HCI. However, HCI has also often failed to consistently see innovations through to implementation in the real-world [55]. In many cases, digital health interventions are designed or created, but not actually implemented or scaled [74]). This phenomenon has led to the development of the term "pilotitis" as a critique of the overuse of pilot projects or studies that never lead to larger-scale implementation [73]. This issue extends beyond the field of HCI alone, and is a challenge faced by many researchers using similar methods, such as human-centred design and participatory design. A recent scoping review of the use of human-centred design methods for health equity in digital health found that while most studies meaningfully engaged community participants in the design process, they did not extend beyond pilot projects [27]. The authors concluded that human-centred design holds promise for advancing health equity in digital health, but they noted that this promise has not been translated into impact beyond pilot projects. Similarly, Saad Sulonen (2020) critiques the field of participatory design for focusing too much on academic projects without addressing scale and replicability, or reaching mainstream implementation [82].

The challenges of moving beyond small-scale projects or pilot studies in digital health is a significant issue that warrants attention, as a huge amount of resources and time are devoted to these projects that do not result in meaningful impact for communities. This is especially important to address in resource-constrained settings, such as public health systems, and in low- and middle-income countries, and when working with marginalised communities, to avoid "extractive" design research where the community contributes to the design process but receives no lasting positive impact in return [39].

The issue of digital health interventions failing to reach real-world practice is caused by many factors, one of which is that digital health interventions often do not adequately consider contextual or implementation factors in the design process. Mohr (2017) describes how technology-enabled services are often developed by academics or developers who are not part of the settings where they will be implemented [65]. As a result, the designs often leave out key considerations such as requirements, processes, constraints, or communication needs, or information technology needs. Nyatuka et al., (2019) also found that stakeholders, beyond those who are the immediate end-users of the digital health intervention, may not be systematically considered or included in the design process [70].

Of course, there are some digital health interventions that have been successful at achieving real-world implementation or scale. For example SilverCloud, which provides evidence-based mental health practices via a digital platform [72]. However, there is often no clear process or documentation to help future projects learn from these implementation successes [8]. We propose that the integration of implementation science methods into the design process could address this gap.

2.2 How Can Implementation Science Help Improve Digital Health Design?

Many health interventions, beyond digital health alone, face the same issues with research waste. Only 1 in 5 make it to routine practice, with factors such as strict adherence to interventions rather than ongoing adaptation, research support being withdrawn, and lack of planning for sustainability being common barriers [15, 47, 85]. That is, health interventions are more than likely to fail, to be used at scale, extended to other contexts, and maintained over time.

Development of successful health interventions relies on the appropriate use of theory and evidence to increase effectiveness. Traditional health research follows a linear path involving strict data collection and analysis in controlled environments (i.e. Randomised Controlled Trials) [10]. This adherence to linear creation and evaluation attempts to ensure rigorous production of evidence, but also means protracted timeframes. On average health research evidence takes 17 years to reach the intended population in practice [67]. This delay is particularly concerning for digitally mediated interventions, as technology continues to change at a rapid pace, the intervention is likely to become obsolete faster [57, 75].

These health intervention challenges have been the exploration and raison-d'etre of implementation science. Implementation science is the scientific study of methods to increase the uptake, implementation, and maintenance of evidence-based interventions (practices and policies) in real-world settings and draws on foundations in psychology, public health, social science, business and health professions [26]. Implementation science is concerned with speeding up the research pathway and ensuring evidence-based practices reach their target populations as intended, can be scaled to additional contexts, and maintained over time beyond the research phase [47].

A commonly used analogy to describe implementation science likens an evidence-based intervention to a drug or pill, and implementation science is used to scientifically explore how the pill is delivered. The strategies used to implement evidence-based practices are referred to as 'implementation strategies'. Implementation strategies are defined as "methods or techniques to enhance the adoption, implementation, and sustainability of an (evidence-based) clinical program or practice." [78]. Most implementation efforts will require changes at the individual, organisational and system levels [61]. The Expert Recommendations of Implementation Change (ERIC), provides a useful taxonomy of implementation strategies focused on organisational and system influences of implementation [76, 87]. A complementary taxonomy focused on changing individual's behaviour is the Behaviour Change Technique (BCT) Taxonomy [63]. In contemporary implementation science, the identification, development and testing of implementation strategies is a priority [76] .

Implementation science has seen an exponential increase in its research and application over the last two decades and a substantial increase in funding [47]. Originating in the health field, its scope of practice has been slowly increasing and having impact on additional contexts such as education, climate change, and veterinary science [66, 68, 79]. Implementation science helps researchers and practitioners to understand and plan for the implementation of evidence-based interventions through a number of theories, models, and frameworks gathered from across implementation science and implementation science-related fields. However, with over 150 different theories, models and frameworks, it can be overwhelming for newcomers to the field [1, 23, 69, 89]. This has motivated our selection and use of a single implementation science framework (described more below in 2.4) that we feel could be most beneficial to HCI researchers and designers undertaking digital health design.

2.3 Integrating HCI and Implementation Science

Previous research has considered how implementation science could benefit from HCI, but not so much the reverse. For example, Dopp et al., (2020) have discussed how user-centred design methods may benefit implementation science researchers and practitioners [25]. Mohr et al., (2017) also propose an 'Accelerated Creation-to-Sustainment (ACTS) model' to design and implement a mental health technology-enabled service which calls for iterative design and evaluation across three stages: create, trial, and sustain [65]. Lyon et. al (2020) describes how core implementation science methods can also be improved using human-centred design methods [25]. Dopp et al., (2020) explore the commonalities between implementation science and user-centred design through concept mapping with experts from both disciplines and found a number of overlapping

clusters - "understanding systems and contexts", "co-designing solutions" and "promoting leadership and collaboration". The article provides high-level guidance on how implementation science and user-centred design researchers could work in parallel or sequentially throughout projects to build on the strengths of their own disciplines. However, echoing others, Dopp et al., (2020) call for clear integration of frameworks to bring the two fields together and explicitly describe how to design for implementation [25, 25, 65].

It is important to acknowledge that the integration of implementation science into design is not the only way to take contextual factors into account. For example, the field of service design focuses on wider contextual factors, such as the implementing organisation and the role of stakeholders beyond the core end-users, more so than user-centred design or participatory design. It includes tools for mapping ecosystems, stakeholders, and systems and can expand the scale of design to have a broader, more systemic perspective [82]. Service design aims to completely redesign a service within an organisation to promote better service experience and outcomes [42]. Within healthcare specifically, iterative learning cycles are used to explore and make changes to the service to reach the "triple aim" - improving healthcare outcomes, reducing costs, and improving the patient experience. Service design views technology as one part or tool to achieve these aims and suggests that technology should be introduced iteratively through learning cycles [40, 84]. However, we argue that implementation science is the best tool to use for digital health design specifically, as it is more theoretically driven than service design and the use of frameworks, models, and focus on implementation strategy reporting in implementation science has enabled the replication of methods [69].

Given these strengths of implementation science and the remaining gaps in design practices of digital health interventions for real world implementation, we propose the integration of a technology-specific implementation science framework (NASSS, described further below) within a human-centred design process. In the following sections, we will outline our proposed approach and demonstrate its use through a case study focused on the design of a digital health intervention to reduce alcohol consumption among women at risk of breast cancer.

2.4 Nonadoption, abandonment, scale-up, spread and sustainment (NASSS) Framework

Implementation science frameworks differ in their purpose (i.e. how they aim to describe, inform or evaluate implementation); conceptual level (i.e. focusing on the individual or organisation; degree of theory used; and the degree to which they can be operationalised (i.e. associated tools or methods to promote application) [76]. To aid selection of which framework to use when, Nilsen and colleagues (2015) broadly categorised implementation science frameworks, theories and models into five categories - process models, determinant frameworks, classic theories, implementation theories, and evaluation frameworks [69]. Process models focus on guiding research evidence into practice through a stepped process (e.g. the Knowledge-to-Action model [31]). Determinant frameworks focus on predicting or explaining factors affecting implementation by identifying contextual barriers and facilitators (e.g. Consolidated Framework for Implementation Research (e.g. The Consolidated Framework for Implementation Research (CFIR) [24]). Classic theories are those from other fields such as psychology and social science (e.g. Theory of Diffusion [81]). Implementation theories are those that have been developed within implementation science to explore or understand specific aspects of implementation (e.g. Organisational Readiness [93]). Evaluation frameworks provide guidance for how to evaluate the implementation of an evidence-based intervention (e.g. RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) [30]). Determinant frameworks are the most suitable for designing interventions [9] as they seek to explore and understand multiple and multilevel contextual factors (or domains) that are hypothesised to impact implementation outcomes [69].

NASSS is a multi-level theoretical model, developed by Greenhalgh and colleagues in 2017 [35]. Although produced after Nilsen's classification article [69], NASSS would be considered a 'determinant framework' as it allows researchers to surface and explain the multiple influences on the adoption, scale up and sustainability of technology in health and social care [35] . NASSS is just one of a plethora of implementation science frameworks. However, for our study it has a particular salience due to its specific focus on technology implementation, multiple conceptual levels, strong theoretical basis, and its operationalisation. The development of NASSS was based on a synthesis of literature on technology-enabled care initiatives alongside six longitudinal case studies. This resulted in technology specific considerations that aims to move beyond pilot projects to embedding health technology in organisations as 'business-as-usual' [35]. Users of NASSS are asked to consider technology implementation factors such as material and technical features of the technology and procurement of digital technology. At a conceptual level, NASSS encourages users to explore the individual, organisational and system-level factors contributing to implementation across seven domains (described below). Theoretically, NASSS is underpinned by complexity theory which highlights potential "uncertainties, interdependencies and possible unintended consequences" [34, 35].

The developers of NASSS have highlighted the importance of understanding the interactions between different sociotechnical domains to explain why a technology is either adopted and maintained or not in health and social care. The framework identifies seven interacting domains, including:

- the condition or illness (e.g. nature or the condition, relevant comorbidities),
- the technology (e.g. key features, knowledge needed to use/support it, usability, dependability),
- the value proposition (e.g. business or economic case, desirability, efficacy, safety),
- the adopter system (e.g. changes to staff roles and practices, acceptability by patients),
- the organisation (e.g. organisational capacity to innovate, readiness for change, impact on processes/routines, resources),
- the wider system (e.g. policy context, regulatory context, position of professional bodies), and
- emergence over time (e.g. scope for adapting and evolving) [35].

Each of the domains can be complex (several interactive components acting in dynamic or unpredictable ways), complicated (several components acting in more predictable ways), or simple (few components that act in predictable ways [3]. The development of NASSS also provides useful tools to aid operationalisation of the approach. Building on the analytical framework, NASSS Complexity Assessment Tool (NASSS CAT) was developed as a practical instrument to help stakeholders and implementation teams plan, monitor and guide development and deployment projects as they unfold. It consists of a series of questions to prompt project teams to consider how they might manage or reduce complexity across the different domains [33]. The tool is publicly available (visit [33]).

Multiple case studies demonstrated the use of NASSS retrospectively or in real time to investigate potential or emerging challenges when implementing existing technology [3, 35, 36]. For instance, Bright et al., (2023) used NASSS to identify the contextual factors that contributed to the inter-district variation in the adoption of a novel maternity care vital signs alert in Sierra Leone [11]. NASSS domains and complexity ratings were used to deductively analyse interviews with stakeholders involved in the technologies implementation. Variation in adoption was due to complexity in the 'technology' and 'organisation' domains including infighting across the workforce, high staff turnover, and issues with production and charging the technology. These results severely affected the adoption of the technology across locations and are seen to be crucial to address prior to further spread and scale [11].

We make no specific claims as to either the ease of which other implementation science frameworks might be used in a similar integration of human-centred design and implementation science, nor to the uniqueness of NASSS in this respect. The framework's development and examples of its application, as an analytical tool to identify and tackle barriers and complexities associated with technology-driven changes in particular, was the basis for our selection. In the paper we explore how this system perspective can be applied alongside the processual approaches inherent within design frameworks; specifically the Double Diamond.

2.5 The Double Diamond

The British Design Council described the Double Diamond as "a visual representation of the design and innovation process... a simple way to describe the steps taken in any design and innovation project, irrespective of methods and tools used" [20] . Typically depicted as two horizontally adjacent diamonds, the representation emphasises the nature of progression in design through four different phases of diverging and converging thought to arrive at a design solution. The four phases in which a designer's data, understanding and imagined possibilities and solution iteratively diverge and converge. *Discovery* which involves exploration of the problem space (divergence) is followed by *Definition* sensemaking and analysis with the goal defining the challenge and developing the design brief (convergence), *Development*, which involves the creative production and refining of possible solutions (divergence), and *Delivery* in which a subset of preferred candidate solutions are prototyped, tested, extended and refined (convergence) [20]. Within each phase, designers can pick from myriad methods and activities, such as user journey mapping and interviews to discover and define problems, or think-aloud sessions and user testing to develop and deliver solutions. It is also important to note that the articulation of design as four sequential phases were developed to help describe the nature of progression through a design process. As such, it, would be incorrect to infer that design progresses is a strictly linear manner through the phases, as it can, and typically does involve iteration across and within phases [20].

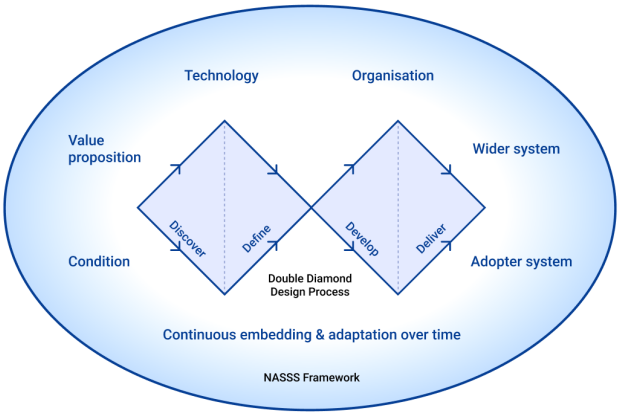

Figure 1: Our proposed approach to integrate the Double Diamond process and NASSS framework

3 PROPOSED APPROACH

3.1 Our proposed approach: Integrating NASSS with the Double Diamond process

In this paper, we propose an approach to integrating an implementation science framework (in this case NASSS) with human-centred design. Furthermore, with do this with an understanding of the design process as is articulated by the British Design Council's Double Diamond process [20] (see Figure 1). As already described, the Double Diamond process does not commit designers to particular methods within each phase, and specific design methods are many and varied depending on a designer's conceptualisation of the design problem. For example, the value-centred designer would typically initiate a design process with the mindset of uncovering the core values rather that identifying unmet needs, whereas the participatory designer would focus on how stakeholders are best empowered in the design process. In our case, in undertaking human-centred design, our focus is on methods that promote empathetic engagement with users. Yet when one conducts value-centred, participatory or human-centred design, in almost all cases they are configured in accordance with the four phases of the Double Diamond. This likely goes some ways toward explaining its popularity and application in commercial product and service development[12]. Another is its flexibility to adapt to different contexts and frameworks [14, 22, 28, 96].

Following the Double Diamond approach, we propose a way to integrate NASSS concerns with common design methods at each

phase. In essence, our approach is an attempt to use the concerns highlighted by implementation science to scope design activities and stakeholders using NASSS at different points in the design process where they make the most sense. Meanwhile, the iterative nature of the Double Diamond is likely to be beneficial to implementation science practitioners looking to expand their design thinking. This is a potentially rich and mutually beneficial integration and one that is not only accessible to designers but health researchers and practitioners as well. It is worth noting that although our approach uses the NASSS framework, other implementation science frameworks could also be integrated. Furthermore, prior to using this approach, the team (any combination of designers, health researchers, and practitioners) should establish the 'issue' being solved using technology; the likely end-users of the technology; and the organisation or system in which it is to be implemented.

In the below section, we outline our proposed approach (integrating NASSS within the Double Diamond) before turning to our example case study (section 4). The case study serves as a detailed exploration of how our approach can be pragmatically applied in a real project. Although empirical results are not the aim of this paper, we utilise our example case study as a reflective tool to explore our own experience, and to discuss future directions and considerations of the approach. A table depicting each step, detail, key considerations and reference to our example application is available at table 1.

3.2 Discovery: Scaffold exploration to consider broad factors of implementation (who should be involved and what should be questioned)

- Identify relevant stakeholders
- Identify relevant evidence sources to explore each NASSS domain

The first phase, discovery, refers to the diverging exploration of primary and secondary data sources to understand and question the design problem and explore the needs of potential users and other relevant stakeholders. Inevitably the scope of the discovery phase is bounded by resources (people, time and access to stakeholders) and is preconfigured in relation to prior knowledge, experience and assumptions of design teams. This preconfiguration may mean key implementation factors are excluded. By its very nature, NASSS is a distillation of domains (domains that were systematically identified in the formulation NASSS) that are relevant to the success or otherwise of a digital health implementation [35]. NASSS domains therefore serve as empirically established heuristics for the scope of the discovery phase. Scaffolding enquiry through NASSS domains encourages diverging exploration (i.e. across individual, organisational and system level influences) while also bounding enquiry to elements that influence successful implementation. In order to investigate each of the domains, design teams have to systematically consider how to explore each domain (i.e. what evidence to consider), what evidence is collected, and from whom. In the first step, teams should use the NASSS domains to systematically identify relevant stakeholders who have expertise pertaining to the particular domain. For example, front line staff are likely to have oversight over the adopter system (what changes in staff roles would be needed) and organisational domains (what work might be involved in implementing change and who is likely to implement it). Inevitably, some stakeholders may be unavailable, teams should find representatives that can speak on their behalf (for example speaking to a lower level government official rather than minister). Additionally, some stakeholders will have expertise and oversight over multiple domains or may be able to recommend colleagues. Stakeholder mapping [13] is a useful exercise to determine who is involved in each domain and the potential interdependencies. Practically, teams could pictorially map each domain and stakeholder and use arrows to depict the interdependencies between each. Following this step, teams should look to explore each NASSS domain by collecting relevant data. Data from different disciplines will be relevant depending on the 'issue', potential technology, and context in which it is to be implemented. Primary and/or secondary data may be relevant. For example, previously published HCI literature is likely useful to explore how the technology in question has been used and evaluated in the past (i.e. for the condition and technology domains), while the implementation science literature may point to implementation strategies that have worked in similar contexts (i.e. under the organisation domain). Primary data collection should be informed by NASSS domains and can be used to inform emerging gaps in the secondary data available.

3.3 Definition: Make sense of the insights gathered and frame the design space according to NASSS domains

- Analyse and synthesis evidence gathered
- Prioritise to reduce implementation complexity and establish a design brief

In the definition phase, HCI researchers and design practitioners typically engage in a series of sensemaking activities and process of convergence to align findings to the overall goals of the project. Using NASSS to analyse and synthesise the insights surfaces design considerations that either enable or hinder intended outcomes. These considerations can then be addressed in the latter phases of the design process. The goal of this process is to ensure that the design adequately addresses implementation-specific considerations, to focus the process of iteration and prevent waste (i.e. time, money, other resources) [54]. Without considering implementation science principles, designers could potentially design technology that is unfeasible, for example, designing a technology that creates additional workload for clinicians, or cannot be integrated with the service's current technological infrastructure. In practice, design teams can use the NASSS domains as a frame to either inductively or deductively analyse the data from the discovery phase. If deductively analysing the data using NASSS, teams could identify relevant data that pertains to each of the domains and create insights from the analysis of the data under each domain. An inductive approach might involve developing insights from the data prior to mapping the insights to the NASSS domains. In both instances, teams should look to identify real or potential complexities within domains and interactions across domains. The NASSS-CAT [33] provides structure through which to explore the complexity within each domain.

Table 1: Approach to conducting NASSS-based implementation research to design digital health technologies

Steps	Key considerations	Example application
Discovery: Scaffold exploration to consider broad factors of implementation (who should be involved and what should be questioned)		
Identify relevant stakeholders Systematically identify relevant stakeholders who hold information on each NASSS domain	• Stakeholders may be relevant to multiple domains or only partially relevant to certain domains. • Find representative stakeholders if the primary stakeholder is not accessible (e.g. speaking with a manager instead of the CEO)	• Stakeholder mapping (section 5.1.1)
Identify relevant evidence sources to explore each NASSS domain	• Explore each NASSS domain through the collection of primary and secondary evidence from different sources and disciplines (i.e. public health, HCI) • Follow rigorous methods for the specific discipline • Explore and identify potentially relevant implementation science strategies • Existing NASSS tools are available for certain data collection methods • Stakeholders may be able to provide direction regarding what data to collect	• Ex-post analysis of previous trial data and literature review (5.1.2) • Co-design workshops with women (5.1.3)
Definition: Make sense of the insights gathered and frame the design space according to NASSS domains		
Analyse and synthesise the evidence collected	• Extract design considerations for each NASSS domain • Use NASSS to analyse data inductively or deductively • Consider complexities within different domains and interactions across domains, there are available NASSS tools to determine complexity (e.g. NASSS CAT) • Contextualise possible implementation strategies	• Thematic analysis using NASSS domains (5.2.1)
Prioritise to reduce implementation complexity and establish a design brief	• Prioritise design considerations with the aim to reduce complexity, select appropriate implementation strategies and establish a design brief • Select appropriate implementation strategies • Ensure design brief is accessible to team members and stakeholders	• Prioritisation and design brief development (5.2.2)
Development: Explore different ways to respond to the design brief using NASSS to guide the ideation process		
Ideate potential solutions to respond to the design brief	• Potential solutions should aim to to reduce complexities within and across each NASSS domain specified in the design brief • Utilise established idea generation techniques and tools • Engage NASSS-defined stakeholders to ensure all domains are covered	• Ideate potential design solutions by contextualising existing evidence using How might we" questions (5.3.1)
Validate design assumptions	• Develop tangible representation of the design and share it with relevant stakeholders to elicit gaps and identify unintended complexities • Validate the design against NASSS domains to ensure all relevant complexities have been considered • Invite stakeholders who can speak to each NASSS domain as critical friends	• Validate design asumptions using mock-ups and critical friends(5.3.2) • Addition of a pilot arm within the trail (5.3.3)
Delivery: Structure the testing and evaluation of prototypes based on NASSS domains and prioritise and test findings accordingly		
Test and refine the design to ensure it reduces complexity	• Use NASSS domains to systematically test the design and surface factors contributing to complexity or unintended outcomes • Make use of established user testing methods with the explicit intention of exploring NASSS domains with stakeholders • Consider iterative testing and refinement with the end goal of reducing complexity within and across NASSS domains	• Prototype testing and design iteration (5.4.1) • Focus group discussions with clinic staff members (5.4.2)
Implement and evaluate	• Implement and evaluate the design solution in the organisation or system for which it is designed • Choose appropriate study methods to measure both effectiveness and implementation outcomes • Use NASSS to explore stakeholders' experience of implementation. Use findings to inform future iterations • Apply evaluation specific frameworks (such as RE-AIM) to quantify implementation outcomes • Document implementation strategies	• Trial implementation and evaluation (5.4.3)

Implementation strategies identified in discovery should be contextualised and prioritised as not all will be suitable. For instance, previous research may show 'create new clinical team' [76] as a possible strategy, but such a strategy might not be feasible in the context in question. Whereas 'conduct educational outreach visits' might be more feasible.

The use of NASSS in this phase may elicit additional factors that would not usually be explored. To ensure assumptions are not leading design choices, there may be a need to further explore elements of each domain. A key benefit of the Double Diamond is that it encourages iteration across and within phases. For example, designers could use the findings of the synthesis to further test assumptions through sensemaking workshops or interviews.

Inevitably, there will be myriad design considerations that could be addressed. NASSS recommends focusing on reducing complexity as a means through which to prioritise which design considerations to focus on. Practically, teams could map out potential design considerations using the NASSS-CAT and explicitly prioritise the design considerations that are either 'simple' or could move 'complex' issues to 'complicated' or 'complicated' to 'simple'. Once prioritised, the design brief should reflect the prioritised design considerations for which the intervention is to be designed. The design brief should prioritise simplicity, be informed by the NASSS domains, and be accessible to other members of the team who may not have been involved in previous steps. At the end of the definition phase using NASSS, designers should have a deeper and more nuanced understanding not only of the user needs, but how these relate to the broader context in which the technology is to be designed and used. The definition phase eventually culminates in a design brief that prioritises simplicity and is informed by NASSS domains.

3.4 Development: Explore different ways to respond to the design requirements using NASSS to guide the ideation process

- Ideate potential solutions to respond to the design brief
- Validate design assumptions

The Double Diamond process encourages designers in this second diamond to shift their focus from understanding the problem space to finding solutions to respond to the design brief, answering 'how might we' to each of the design problems elicited. Ideally at this phase, designing with implementation in mind ought to be a straightforward process as implementation-specific considerations should have already informed the development of the design brief using NASSS. But in reality, as in other design endeavours, some design considerations only surface when discussions are supported with tangible design artefacts. At this phase, there is a tendency among designers to focus on the intervention design and neglect or pay less attention to other important implementation elements, particularly organisation and wider-context domains. This can lead to assumptions that can have significant impact on real-life implementation of the design. As argued by Greenhalgh and colleagues (2017), failure to design for these broader factors will result in technologies that work for local demonstration projects but are not adopted for business as usual, transferred to new services and maintained over time [35]. It is therefore important to reinforce NASSS domains by intentionally embedding them within the ideation and testing activities. Any potential solutions should attempt to reduce complexities identified in the definition phase both within and across each NASSS domain. Designers should use established idea generation tools and techniques (e.g. "how might we" questions) and ensure relevant stakeholders are included. Next, designers should develop a tangible representation (e.g. mock-ups) of the design to validate design assumptions. Validation should ideally include stakeholders with varying degrees of expertise (e.g. as critical friends) across domains to check that assumptions made by designers are in fact accurate to their experience and expectations of the technology.

3.5 Delivery: Structure the testing and evaluation of prototypes based on NASSS domains and prioritise and test findings accordingly

- Test and refine the design using NASSS domains to ensure it reduces complexity
- Implement and evaluate

The delivery phase explores the effectiveness of the design solution by systematically testing with selected groups of stakeholders to gather feedback and recommendations to further refine the design. Designers in this phase should test and refine the design prototype using the NASSS domains to again surface any factors contributing to complexity or unintended consequences. Commonly employed user testing methods are recommended to explore interactions between users and the technology. User testing and/or additional data collection methods can also be extended to explore additional NASSS domains. For example, user testing with frontline staff might also include additional questions about the organisation or wider system such as any unintended consequences of the workflow in relation to their regulatory body, or how the technology might be adapted and scaled to new services. We suggest design teams engage in an iterative approach to test and adapt the technology based on users' feedback with the goal of developing a technology that reduces complexity across domains and can be implemented within the service. Finally, teams will have developed a solution that can be implemented in the organisation or system for which it was designed. The intervention including the design solution and implementation strategies should be appropriately documented to allow others to learn from, replicate and adapt the intervention. There are a number of useful frameworks to facilitate reporting such as the Action, Actor, Context, Target, Time (AACTT) framework [77] and Proctor and colleagues' guidelines for reporting implementation strategies [78]. Inevitably, resources will constrain the extent to which the technology can be implemented and evaluated in practice. In any case, prior to implementation we recommend designers develop measures to collect relevant data for both the effectiveness of the technology as well as implementation outcomes. There are commonly used implementation evaluation frameworks and tools to guide this approach such as RE-AIM which scaffolds the measurement of reach, effectiveness, adoption, implementation and maintenance [29, 30]. NASSS is also useful to evaluate the success of implementation and to explore stakeholders' experience of implementation [35]. A useful study design to measure

both implementation and effectiveness is a hybrid implementation-effectiveness trial [21] which can used in both larger trials and smaller pilot projects [56].

4 FINDINGS - EXEMPLAR CASE STUDY

4.1 Case Study Context

We demonstrate our proposed approach in redesigning a digital health intervention targeting women attending routine breast screening services, with the goal of reducing their alcohol-attributable breast cancer risk. This case study was selected as exemplifies the potential for HCI research to have impact through implementation in a health service and to address both HCI and implementation research questions. Below, we outline the context and impetus for design. Thereafter we provide a detailed account of how we incorporated NASSS at each phase of the design process following the Double Diamond (section 5). The account is not intended to provide a prescriptive application of the approach, rather it provides an example of how one could apply the approach in practice. It was intentional on our part to focus on the case study's design activities rather than its empirical accounts (which will be reported elsewhere) to reflect on the utility of our approach, challenges and opportunities for future work.

4.1.1 Context. Alcohol is a major modifiable risk factor for female breast cancer, with meta-analyses demonstrating increased breast cancer risk at even very low levels of consumption [7, 18]. Yet, awareness of this risk remains low [4, 37, 86], and is not systematically addressed in healthcare settings. While alcohol consumed at any point in life is relevant to breast cancer development, recent intake, particularly after 40 years of age, is strongly and independently associated with breast cancer risk [17]. In Australia, while alcohol consumption is declining, risky drinking has increased significantly among midlife and older-aged women [64, 71], a trend that has also been observed in other countries [45]. However, midlife and older-aged women's drinking remains largely overlooked [80], and has not been a target of large-scale breast cancer prevention efforts. Population-based breast screening programs are uniquely positioned to provide timely and targeted health information and behaviour change strategies to improve women's alcohol literacy and reduce consumption, with potential for extensive reach [37].

The original design of the brief alcohol intervention Health4Her, included four minutes of alcohol-related information (personalised feedback on consumption level; negative-framed messaging about the risks and harms of alcohol use with a focus on increased breast cancer risk; positive-framed messaging about the health benefits of reducing alcohol use; alcohol harm-reduction strategies) and three minutes of general lifestyle health promotion, delivered in the breast screening clinic via an iPad. The original Health4Her was designed in collaboration with potential users of screening services (women enrolled in the Health4Her project aged 40 years and older and eligible for screening mammography). The initial design was informed by a literature review of general behavioural strategies to reduce alcohol consumption. Then, researchers developed a visual depiction of the content and order of contents within the planned design and collected participants' feedback on the format and content. An external company was engaged to create the animations within the intervention. The study procedures were also developed in consultation with women. For example, ensuring all women (no matter their risk level or past history of breast cancer) were eligible, introducing the study prior to their appointment, and hiding the focus of the study (alcohol) to encourage all women, no matter their consumption level, to take part.

The Health4Her intervention was tested using a hybrid type 2 effectiveness-implementation trial [21] comprising a randomised controlled trial (RCT) alongside a mixed methods program evaluation at Maroondah BreastScreen between February and August 2021. The aim of the study was to test the effectiveness of the intervention in increasing women's knowledge of alcohol as a breast cancer risk factor (primary outcome); improve women's alcohol literacy; reduce consumption of alcohol; and examine the implementation of the intervention within the service (secondary outcomes). Participants were randomised to receive the active intervention (animation including brief alcohol intervention and general lifestyle health promotion) or control intervention (animation including general lifestyle health promotion only) after their screening appointment. Pre-implementation and program evaluation was conducted with women and staff working at the clinic following the trial. For in-depth results please see published results available elsewhere [38].

4.1.2 The need for redesign. Although the Health4Her intervention had positive effects on knowledge, alcohol literacy and was acceptable to women and staff members, there were a number of areas for improvement. Most importantly, the Health4Her intervention did not reduce alcohol consumption. It was unclear whether the lack of behaviour change was due to the study's lack of power to detect change in consumption (the power calculation was determined based on improving knowledge, the primary outcome, rather than consumption, a secondary outcomes), or whether the intervention itself was not sufficient to result in behaviour change . Additionally, personalised alcohol health advice was delivered according to a binary classification of alcohol-related risk based on national guideline recommendations (i.e. exceeding/not exceeding guidelines); such an approach may not have promoted reduced consumption among women drinking within guideline recommendations, though who may still be drinking at levels that increase breast cancer risk. From an implementation perspective, many women declined to participate due to lack of time (e.g. work commitments, going away, metered parking, or being dropped off/picked up from their appointment). Staff suggested that there may be challenges with implementing future iterations of the Health4Her intervention at other sites, depending on their staff numbers, staff workloads, staff willingness to provide iPad troubleshooting support for women, and available space.

These implementation challenges and lack of effectiveness in reducing alcohol consumption were the impetus for the intervention's redesign and a further trial using a hybrid-type 2 effectiveness-implementation approach [21]. Our research question was therefore, how might we re-design Health4Her (Health4Her-Automated) with a focus on effectiveness, implementation, scale-up and spread, while ensuring that the design is evidence-based, considers implementation and ensures end-users and stakeholder and involved

meaningfully throughout. Below, we outline our approach to integrating NASSS within the Double Diamond, and the associated activities within each phase. Although we describe the process in a linear fashion, it is important to note that in line with the Double Diamond there were a number of iterations within and between steps.

5 APPLICATION OF APPROACH

5.1 Discovery

5.1.1 Stakeholder mapping based on NASSS domains. Prior to commencing our exploratory design process, we systematically identified and mapped relevant stakeholders who have expertise in specific NASSS domains that we could draw on at different phases of the design process. We established working relationships with various experts from different disciplines (i.e. public health, HCI, implementation science, and behaviour change). We identified frontline staff and decision-makers within the Maroondah BreastScreen clinic who could be engaged to explore organisational and wider-system factors that could affect Health4Her implementation. We also recruited women from the LifePool Project to understand the end-user's perspective on alcohol consumption, their needs and values, and their technological capabilities. Knowing who we could and should involve at the start of the design process allowed us to organise specific design activities that scaffolded our exploration of factors that could have significant impact on implementation. Having regular consultations with these stakeholders at different phases of the design process also prompted us to refrain from adding unnecessary complexities to the design. Likewise, our design activities in the discovery phase were purposefully planned to explore concepts related to each NASSS domain. An important consideration that emerged in this phase of the process was the constraints imposed by the trial where the case study is based, we discuss this further below.

5.1.2 Ex-post analysis of previous trial and literature review. Our discovery phase included an ex-post analysis (reanalysis after the fact) of the previous trial and program evaluation using NASSS. This process allowed us to elicit key implementation barriers, especially around the use of technology, and prioritise specific issues that needed to be changed to increase the effectiveness of the intervention while ensuring implementability. For example, under the organisation domain, staff reported they would have preferred the intervention to be delivered on personal devices as this would reduce the need for staff troubleshooting women's issues with the iPads (organisation domain). Under the technology domain, it emerged that the tone of the original intervention was perceived as condescending to some women. While under the condition domain, it was evident that wider social-cultural factors were a key factor, especially the use of alcohol to relax or celebrate. These and other insights guided the development of specific questions to explore with women to guide the design process. Although not specifically guided by NASSS, extensive literature reveals health interventions using evidence-based Behaviour Change Techniques are more successful than those that use generic approaches [62]. Behaviour Change Techniques tend to focus on individual level factors and are often used in tandem with implementation strategies that focus on organisational or system level factors. The previous design of Health4Her did not utilise the Behavioural Change Technique approach or specify implementation strategies suing the ERIC framework [62, 63]. In order to address this shortcoming and design for increased effectiveness our behavioural experts conducted a literature review of high quality review level evidence on effective Behaviour Change Techniques for reducing alcohol consumption via digitally mediated brief alcohol interventions. Key Behaviour Change Techniques elicited were Problem Solving, Behaviour Substitution, Credible Source, Goal Setting and Information about Antecedents [44, 62]. We also looked to the implementation literature to explore potential implementation strategies using the ERIC taxonomy [76] that could address some of the implementation related issues identified in the ex-post analysis. Potential strategies included changing how the intervention was delivered ("change physical structure and equipment") and allowing participants to share what they learned with friends and family ("increase demand").

5.1.3 Co-design workshops with women. We conducted two sets of co-design workshops with women, one for those who drink below the Australian alcohol consumption guidelines (i.e. no more than 10 standard drinks per week and no more than four on any one day) (n=8) and those who drink above (n=6) to explore NASSS domains requiring end-users involvement and expertise. Workshops involved contextual understanding of the technology's ease of use (technology), values around alcohol consumption (condition, adopter system), their sense of broader needs of their peers (adopter system), and their perceived needs in relation to health promotion and the screening service generally (value proposition, organisation). We also took this opportunity to explore how the Behaviour Change Techniques could be contextualised and incorporated into the design. We did this by sensitising the women to different health promotion interventions, including the previous Health4Her, and then asking them to rank and discuss information and scenarios related to different Behaviour Change Techniques (condition, adopter system, wider context). In these workshops, we paid particular attention to women's socio-cultural values (i.e. the importance of celebration with alcohol) and context-related considerations (i.e. exploring how best to include evidence-based guidelines) in order to ensure the redesigned intervention was relatable and had perceivable value among users.

5.2 Definition

5.2.1 Thematic analysis using NASSS domains. We used NASSS in the definition phase primarily as a lens to develop and refine themes and insights that inform Health4Her-Automated design considerations. In practice this meant using an inductive approach to analyse primary and secondary evidence gathered during the discovery phase to establish key themes, then using a deductive approach to select the best NASSS domain for each theme [41]. These themes were refined iteratively across meetings and stakeholder consultations to interpret the data and extract design considerations. We also contextualised potential implementation strategies by discussing how these strategies may be embedded into the design while considering other domains. For example, we explored

changing how the intervention was delivered for example on a television screen in the reception waiting area, or on women's personal devices in addition to or instead of via the iPad ("change physical structure and equipment") and allowing participants to share what they learned with friends and family using social media ("increase demand").

5.2.2 Prioritisation and design brief development. Following analysis, we were left with a large number of design considerations within and across domains with potentially conflicting elements. We used the NASSS CAT complexity rating system to prioritise our design considerations from being simple, to complicated or complex. This allowed us to prioritise design considerations that would increase the effectiveness of the intervention while ensuring the intervention's implementability. We were able to identify the key problem areas that we need to address in the latter phases of the design process as well as design considerations associated with different NASSS domains. We documented our findings in a design brief which outlines the intervention's overall value proposition, technology requirements and constraints, a detailed description of the user, and relevant organisational considerations.

5.3 Development

Redesigning Health4Her-Automated included multiple consultations with different stakeholders to get feedback and insights for specific NASSS domains. This helped our team ground our ideation process to take into account all implementation-specific considerations and avoid adding unnecessary complexities to the design.

We took a conventional approach to our development phase activities. We utilised established design methods such as brainstorming and creating design mock-ups (using narrated drafts of the revised script and animations from the previous trial) to explore potential solutions, verify assumptions, and gather immediate feedback from relevant stakeholders.

5.3.1 Ideate potential solutions by contextualising existing evidence using "How might we" questions. Using "How might we" questions, we explored potential ways of responding to the design brief. In particular, how relevant behaviour change techniques could be contextualised to tackle the identified barriers and opportunities associated with reducing alcohol consumption among women. This step involved multiple ideation sessions, during which we consulted various stakeholders and continuously refined our ideas through iteration.

5.3.2 Validate design assumptions using mock-ups and critical friends. Typically, designers use mock-ups to gather general feedback from users, usually by asking them about what they liked or did not like about the design and how it might be improved [91]. In our case, we utilised this design method to explore topics related to Health4Her-Automated implementation by asking questions related to NASSS domains. We asked the women who participated in our early co-design workshops to review mock-ups, listen to the narrated drafts of the revised animation script, and evaluate the content based on value proposition, and adopter system domains. We asked them specific questions such as "How relatable is this content to you?", "Does it motivate you to make lifestyle changes (why, why not)?". We also shared these mock-ups with experts from different fields (i.e. communications design, clinical psychology, epidemiology) to ensure that the relevant evidence, data and strategies we incorporated in the design were accurate and in line with the intervention's overall value proposition.

5.3.3 Addition of a pilot arm within the trial. As we continued to refine the intervention design, we also continued to refine the RCT protocol, including the study's implementation, outcome measures, and user journey. Similar to the content design, these protocols were shared with different stakeholders and iteratively refined based on their feedback. In order to explore some of the implementation-specific considerations and the most pertinent implementation strategy "change physical structure and equipment", it was necessary to add a pilot arm to the trial. The other potential implementation strategy "increase demand" by encouraging women to share the intervention with friends and family was untenable due to the trial environment. Working within trial environments necessitates adherence to strict standards to ensure primary and secondary outcomes can be directly measured by comparing intervention and control groups. If we were to share information with women outside of the intervention group, there was a chance those in the control could have seen it as well. However, we were able to design a solution to address the previous trial's implementation barriers by including an additional pilot arm in which to test implementation strategy design solutions (i.e. allowing women to use their own personal device to access the intervention following their appointment).

5.4 Delivery

5.4.1 Prototype testing and design iteration. Continuing our design iteration process from the development phase, we developed a high-fidelity prototype, a tangible artefact through which different stakeholders could test and base their design reflections on according to NASSS domains. Stakeholders may have failed to see potential implications of the design in our low-fidelity prototype. As such, we intended to foreground the underlying and potentially conflicting design considerations through a concrete and full representation of our design ideas.

The prototype we developed consisted of the technology (a single page responsive web application) and the updated version of the intervention content, including the narration from a professional voiceover artist and animations developed by a professional motion designer. Multiple stakeholders viewed the prototype, including women, domain experts, and clinic staff. Through testing, we asked a series of questions pertaining to the accessibility of the content and the technology, and the delivery of the intervention within breast screening clinics (technology, value proposition, adopter system and organisation). We asked women how likely they were to participate in the trial (value proposition and adopter system), whether on-site or on their own personal devices, and whether they would require additional support to go through the intervention (technology). Methods also included think aloud, to explore women's interaction with the technology and how they perceived, interpreted and responded to each element.

As we discovered, most women preferred receiving the intervention on their own personal devices, rather than on the iPad in the

clinic. Many also indicated their preference to receive the intervention prior to their appointment so they could participate during their waiting time. However, feedback from staff in the ex-post analysis revealed that delivering the intervention prior to women's appointments would interfere with current workflows consisting of quick turnaround times, which may influence overall screening rates. This concern was shared by other manager-level stakeholders involved in the project. Other insights involved the design of the trial questions, for example, some women were confused by certain questions or were preoccupied with certain elements (i.e. a question regarding processed meat intended to conceal the alcohol primary outcome). Restraints of designing for the trial meant not all insights could be embedded (e.g. changing when women received the intervention). However, many changes could and were made (e.g. refining or eliminating questions) or noted for future iterations outside trial conditions. Multiple rounds of iterative refinement were undertaken with the multidisciplinary team and domain experts prior to the trial commencement.

5.4.2 Focus group discussions with clinic staff members. Prior to the start of the trial, we conducted small focus groups with staff who would be present and involved in the trial. These discussions with the clinic staff mostly revolved around organisation and wider-system domains of NASSS, including topics such as leadership, people, culture, knowledge, resources, and technical infrastructure. Although reflections on these domains do not have a direct and immediate impact on the current intervention's redesign, they do provide insights as to how the intervention could be supported outside a RCT and increase the rate of success of deploying it at scale.

5.4.3 Trial implementation and evaluation. The last activity of our delivery phase will be the execution of the trial. Similar to the initial hybrid-II trial used to evaluate the first iteration, the trial will focus on both the effectiveness of the intervention and the implementability of the intervention. The addition of NASSS-specific measures will ensure technology-specific domains are explored. The trial has been prospectively registered with Clinicaltrials.gov (identifier: NCT06019442).

6 DISCUSSION

In this paper we illustrate a practical approach for integrating implementation science and human-centred design to ameliorate the high failure rate in technology implementation projects using the Double Diamond and NASSS frameworks [32, 89, 92]. Implementation science – the study of how to embed evidence-based practice into real-world contexts using evidence-based strategies presents a valuable contribution to HCI researchers looking to address the large number of digital interventions that do not move beyond pilot phase [73]. HCI researchers' interest in implementation science is clear from the addition of a HCI and implementation science specific workshop at CHI 2023 [55]. The integration of the two fields has been studied in the context of mental health by exploring how user- [54, 65] and human-centred design [54] methods might be embedded in implementation science methods.

This research has offered helpful recommendations focusing predominantly on higher order considerations. Specific processes that operationalise these considerations, specifically within the design phase, are underdeveloped. Furthermore, given the expansive number of frameworks within implementation science, it can be overwhelming and confusing for HCI researchers to select appropriate frameworks to apply in their practice. Our proposed approach of integrating an implementation science framework (NASSS) within a well-known design process (the Double Diamond) provides clear guidance for designers, researchers and practitioners to integrate the two fields. Our proposed approach has been applied in redesigning a brief alcohol intervention that aims to decrease alcohol consumption in women attending routine mammogram screening and provides an additional context for exploration - primary public health messaging delivered in screening clinics. Below we reflect on our approach redesigning this evidence-based intervention with implementation, scale-up, spread and sustainment in mind.

6.1 Using an interdisciplinary approach

We brought together a team from multiple disciplines to re-design Health4Her-Automated, integrating diverse expertise and broad methodological toolkits that are key to complex problem solving in digital health [60]. Members included subject matter experts, implementation science experts, behaviour change experts, designers and engineers. While an interdisciplinary team elicits diverse opportunities and research enquiries, there are challenges in conducting research that integrate HCI and health to build technology [5]. Major challenges are common across collaborations including conceptualising research (i.e. wrangling differences in research paradigms from different disciplines), implementing research (i.e. misalignment in what is considered data), and translating research (i.e. practical nature of technology vs. technical innovation and novelty) [5]. Our redesign of Health4Her-Automated encountered these challenges and was further exacerbated with the added element of implementation science alongside HCI and health.

Our approach of combining NASSS and the Double Diamond highlighted the necessity for an interdisciplinary team that ensures research alignment. This combination was useful to ground our research activities to meet the requirements of all disciplines. For example, a common issue in interdisciplinary teams is the misalignment of research questions. This issue is exacerbated by the tendency to include HCI researchers as 'consultants' rather than in the design of the research project [5]; this is also a common issue for implementation science researchers [94]. To address this, our team was established at the beginning of the project and met over a number of weeks to form the research plan to ensure alignment of research across disciplines. The combination of NASSS and the Double Diamond was also useful as it allowed the team to ground our work in designing for implementation while ensuring the intervention was evidence-based and true to the needs of the users.

Our interdisciplinary approach was helpful in understanding the unique complexities and challenges at different levels involving multiple groups of stakeholders, especially when encountering tension between the needs of the users and health researchers [5]. For example, the previous iteration of Health4Her contained a large amount of statistics and guidelines. Although important from a health research perspective to provide accurate and up-to-date

statistics, it was considered off-putting for some women who felt the overt use of statistics lost the overall message of the intervention, while others felt it was important to provide at least some statistics to add to the credibility of the message. Combining the Double Diamond's approach to discovery (ex-post analysis alongside the literature review and design workshops) was useful to combine both the needs of the women alongside the trial's evidence base, which tend to be focused on as separate priorities for discipline-based enquiries.

6.2 Embedding Implementation Throughout the Design Process

Our approach involved embedding implementation principles within the design process and is specific to designing technology that aspires to be implemented in practice. This approach is in direct contrast to absolute 'blue-sky' thinking or designing configured primarily for novelty. In our approach, we contend with others in the field that HCI has a clear role in the design of digital technologies for use in practice [25, 54, 65, 65]. This approach is in opposition to HCI's technology-centric bias that rewards technological novelty over the pragmatic integration of technology in the real world [19, 59]. Our approach is focused on designing for health outcomes and real-world applicability. That is not to say that different approaches (i.e. rewarding novelty) are not worthwhile, HCI has a multifaceted relationship with digital health and makes important novel contributions. This work attempts to fill key gaps in the HCI and implementation science literature [2, 25, 54, 55]. In order to meet the lofty goal of real-world implementation it is crucial that the design respects the micro, meso and macro level contextual factors it will be implemented in, rather than designing without this scope in mind ('blue-sky' design).

Researchers have proposed utilising an implementation science phase following the design of the intervention, thereby following the traditional linear knowledge generation pathway [16, 65]. However in reflecting on our case study, we contend that implementation should not be a secondary consideration or distal phase. Rather it should be included throughout the design process itself, to scope, prioritise and develop solutions. Without NASSS we may have designed solutions that resulted in research waste (including time and resources), lack of organisational goodwill, unnecessarily wasting research participants' time and input, and the potential to mislead future research in the field. Furthermore, the solutions were established with a need to reduce complexity. Greenhalgh and colleagues (2017) call on technology developers to reduce complexity within and across domains to increase the success of interventions [35]. Designers can use the complexity heuristic to select which design consideration to focus on, for example designing a technology that easily integrates within other systems of the organisation vs. a more complex design that requires the organisation's systems to change to fit the new technology.

6.3 Extending who is considered a 'user'

Nyatuka et al., (2019) found that stakeholders beyond immediate end-users are rarely systematically included in the design of digital health technologies [70]. Failure to include stakeholders beyond immediate end-users risks unintended consequences by failing to explore factors only apparent to those with oversight of organisation and system-level influences. Our integrative approach allowed us to extend the concept of 'user' by recognising that multiple stakeholder groups (e.g. the women, staff at the clinic, the clinical organisations and the health system) can become users or adopters at different levels of the technology implementation. It was necessary to purposefully include stakeholders who could speak to each domain and to consider the input from multiple stakeholder groups holistically rather than separately. This exploration was applicable to the discovery phase of the Double Diamond as we considered multiple sources of research (ex-post analysis, literature review, design workshops) and synthesised the insights from these sources to reduce our assumptions. NASSS domains served as a tool to communicate implementation considerations between groups. More specifically, the domains were used to accurately communicate the needs of others within and across domains in order to facilitate design considerations.

6.4 Limitations of design depending on its place in the process (RCT)

There is increased interest in designing health technologies for scaled and ongoing use across contexts. Given the higher stakes of evidence creation and implementation in health, researchers and practitioners from both disciplines are often faced with designing interventions without 'design freedom'. Much of digital design practice for healthcare has restrictions depending on where designers are brought into projects (i.e. at the outset of evidence generation or to 'digitise' evidence-based practice). RCTs have strict constraints that may severely limit the scope of design work and implementation planning [10]. For example, standardising and controlling-out contextual factors is an inherent aspect of the trial setting, in order to directly measure and compare outcomes for the 'intervention' and 'control' groups (i.e. it cannot be shared on social media). These restrictions were a key consideration in the redesign of Health4Her-Automated and influenced many of the design decisions made, sometimes overriding what was found through the application of NASSS. For example, through our exploration of organisational processes we found from women and staff alike that the intervention could be provided to women on their own device following their appointment, thereby solving the issue of staffing (organisation) and women wanting to use their own device (technology). However, due to the nature of the trial changing the modality was unfeasible as it would introduce a significant confounding effect for this particular phase of the research. Utilising NASSS in this way was helpful as we were able to explore other solutions, eventually landing on the addition of a pilot arm in the trial. In the pilot arm, women are provided with a paper card and a URL link to the intervention; they are then able to do the intervention on their personal device. Other elements elicited through NASSS, such as women wanting to share the link to the intervention with their friends, was not possible in the confines of the RCT, but is planned for future iterations.

6.5 NASSS is one of many relevant implementation science frameworks for design

NASSS is one of many implementation science frameworks, theories and methods. At face value, it is ideal as it is specific to digital health technologies and the specific contextual requirements faced, that are rarely integrated in other implementation science frameworks (e.g. market supply and demand considerations, procurement of digital technology) [35]. Although NASSS provides a structure through which to scope, explore and design digital technologies, it may not be the most suitable implementation science framework for all design work. For example, when exploring and designing for a specific behaviour, a behaviourally focused framework may be more applicable such as the Theoretical Domains Framework alongside the COM-B and related implementation processes [6, 63]. Researchers too, may have their own preferences and expertise in applying specific frameworks and it is likely the use of these would provide similar results. Furthermore, it can be difficult to hold all NASSS domains as equal throughout the design process, and inevitably designers may find themselves prioritising one domain over others. For example, in the development phase we found our team prioritising the condition, technology and value domains over the more distal wider system domains. The reason for this is that we had very little influence or say over the wider system factors influencing the project and as such we focused on and prioritised what we could change within the system. However, NASSS was useful in this process to ground our thinking in domains beyond the technology and to ensure we continuously incorporated future implementation thinking within the development process.

7 LIMITATIONS AND FUTURE WORK

Our study presents a new approach and considerations for how the HCI community and Implementation Scientists can practically integrate the two fields in a public health intervention context. It is important to understand the strengths of the two fields and how researchers can work in collaboration across entire projects by integrating methods to ensure neither is acting as a consultant [5] rather than a true collaborator [25]. Our study provides a worked example of true collaboration and an interdisciplinary team working towards a common goal while pursuing multiple research enquiries. However, more work is needed to expand this way of working across multiple health domains and discipline areas. Previous research by Klasnja et al.,(2011) highlights the tension faced by HCI researchers evaluating digital health technologies when the goal of the technology is to bring about health behaviour change [48]. The authors contend that evaluating a digital health technology based only on the effectiveness of that technology to bring about behaviour change is too narrow and potentially not of interest to HCI if the reasons why the technology worked or did not are not evaluated. They argue for the use of alternative evaluation metrics such as more focused measures of efficacy of the technology to specific behaviour-change techniques and users experiences of these. Likewise, implementation science calls for researchers to look beyond effectiveness alone and to explore the context in which an evidence-based intervention is to be implemented, and the extent to which different strategies help or hinder. In this way the two fields complement each other in that effectiveness is not the only worthwhile measure of a technology's success. Although the overall aim of Health4Her-Automated is to reduce intended alcohol consumption in women attending breast screening services, it is not the only measure of interest. We contend that the use of our approach allowed us to explore both HCI and implementation science research questions in the redesign process prior to the RCT in which effectiveness would be further evaluated. In this way we believe our approach promotes Klasnja et al.'s calls for HCI research of digital health technology for behaviour change [48]. The example case study used to illustrate our approach describes a specific health promotion concern (reduction of alcohol consumption to reduce breast cancer risk) in a specific population (women attending breast screening services) and is not representative of either alcohol consumption generally or breast cancer risk. Additionally, as we recruited our participants through LifePool it does not represent all clients of screening services and favours women who have an interest in breast cancer research or who may be more receptive to this form of health information. The technical system designed in our example (a single page responsive web application) is a relatively simple technical infrastructure with a narrow scope and limited user journey, in line with the scope of the trial. As such, a larger and multiple-user infrastructure will encounter additional complexity in its design. Future work is needed to evaluate our approach in a more complex system, however, the heuristics provided by the domains and complexity scale should work across contexts and capabilities. In fact, the more complex a technology is, the more time should be spent on design to minimise waste [65].

We demonstrate our proposed approach using NASSS and the Double Diamond process. Although the principles behind our approach are flexible and inclusive, specific ways of embedding implementation science principles in the design process may differ with the use of other frameworks. NASSS was chosen as it is specific to the implementation of technology in health services. Compared to other implementation science frameworks this focus on technology is unique to NASSS and a clear strength for those in HCI. However, there are some weaknesses. For instance although NASSS has been widely used since its publication in 2017, there has been a lack of studies synthesising its use compared to other more well known frameworks. Furthermore, NASSS is most commonly used to retrospectively evaluate implementation and is rarely used prospectively or concurrently. Greenhalgh et al. (2017) recommend NASSS to inform the design of technology, however given its lack of use informing design, it may be that as it stands the framework and tool alone are not sufficient to design with or the concepts are not easily accessible to those that design technology [35]. As such we hope our approach can provide additional scaffolding for those looking to use NASSS to inform design of digital health technologies. In particular, it would be interesting to explore how other implementation science frameworks could be used in conjunction with the Double Diamond, we recommend future work be done to explore potential differences in methods or outcomes.

8 CONCLUSION

Researchers and practitioners alike see the potential benefits of combining the fields of HCI and implementation science to design

pragmatic digital interventions for use in the real world. However, there is little practical guidance on how to systematically combine the two fields within a research project. Our goal was to provide a clear process for the integration of the two fields using a well-known design process, the Double Diamond, alongside a technology-specific implementation framework (NASSS). In this study, we explore our approach through a case study aimed at reducing alcohol consumption of women attending routine mammography screening. We hope this adds to the limited, but growing research literature spanning HCI and implementation science by providing a practical worked example of how interdisciplinary teams can collaborate to design for ongoing, real-world impact.

REFERENCES

[1] G. A. Aarons. 2004. Mental health provider attitudes toward adoption of evidence-based practice: the Evidence-Based Practice Attitude Scale (EBPAS). *Ment Health Serv Res* 6, 2 (2004), 61–74. https://doi.org/10.1023/b:mhsr.0000024351.12294.65 Aarons, Gregory A K01 MH001695/MH/NIMH NIH HHS/United States MH01695/MH/NIMH NIH HHS/United States Journal Article Research Support, U.S. Gov't, P.H.S. United States 2004/07/01 Ment Health Serv Res. 2004 Jun;6(2):61-74. doi: 10.1023/b:mhsr.0000024351.12294.65..

[2] G. A. Aarons, M. Sklar, B. Mustanski, N. Benbow, and C. H. Brown. 2017. "Scaling-out" evidence-based interventions to new populations or new health care delivery systems. *Implementation Science* 12, 1 (2017), 111. https://doi.org/10.1186/s13012-017-0640-6

[3] S. Abimbola, B. Patel, D. Peiris, A. Patel, M. Harris, T. Usherwood, and T. Greenhalgh. 2019. The NASSS framework for ex post theorisation of technology-supported change in healthcare: worked example of the TORPEDO programme. *BMC Medicine* 17, 1 (2019), 233. https://doi.org/10.1186/s12916-019-1463-x

[4] R. Agabio, C. Madeddu, P. Contu, S. Cosentino, M. Deiana, E. Massa, A. Mereu, C. Politi, C. Sardu, and J. M. A. Sinclair. 2022. Alcohol Consumption Is a Modifiable Risk Factor for Breast Cancer: Are Women Aware of This Relationship? *Alcohol Alcohol* 57, 5 (2022), 533–539. https://doi.org/10.1093/alcalc/agab042

[5] E. Agapie, Shefali H., and Sharmaine G. P. 2022. Using HCI in Cross-Disciplinary Teams: A Case Study of Academic Collaboration in HCI-Health Teams in the US Using a Team Science Perspective. *Proc. ACM Hum.-Comput. Interact.* 6, CSCW2 (2022), Article 552. https://doi.org/10.1145/3555610

[6] L. Atkins, J. Francis, R. Islam, D. O'Connor, A. Patey, N. Ivers, R. Foy, E. M. Duncan, H. Colquhoun, J. M. Grimshaw, R. Lawton, and S. Michie. 2017. A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. *Implementation Science* 12, 1 (2017), 77–77. https://doi.org/10.1186/s13012-017-0605-9

[7] V. Bagnardi, M. Rota, E. Botteri, I. Tramacere, F. Islami, V. Fedirko, L. Scotti, M. Jenab, F. Turati, E. Pasquali, C. Pelucchi, C. Galeone, R. Bellocco, E. Negri, G. Corrao, P. Boffetta, and C. La Vecchia. 2015. Alcohol consumption and site-specific cancer risk: a comprehensive dose-response meta-analysis. *Br J Cancer* 112, 3 (2015), 580–93. https://doi.org/10.1038/bjc.2014.579

[8] E. Balka, D. Peddie, S. S. Small, C. Ackerley, J. Trimble, and C. M. Hohl. 2018. Barriers to scaling up participatory design interventions in health IT: a case study *(PDC '18)*. Association for Computing Machinery, New York, NY, USA, 1–5. https://doi.org/10.1145/3210604.3210612

[9] S. A. Birken, B. J. Powell, J. Presseau, M. A. Kirk, F. Lorencatto, N. J. Gould, C. M. Shea, B. J. Weiner, J.J. Francis, Y. Yu, E. Haines, and L. J. Damschroder. 2017. Combined use of the Consolidated Framework for Implementation Research (CFIR) and the Theoretical Domains Framework (TDF): a systematic review. *Implementation Science* 12, 1 (2017), 2. https://doi.org/10.1186/s13012-016-0534-z

[10] J. Braithwaite, K. Churruca, J. C. Long, L.A. Ellis, and J. Herkes. 2018. When complexity science meets implementation science: a theoretical and empirical analysis of systems change. *BMC Medicine* 16, 1 (2018), 63. https://doi.org/10.1186/s12916-018-1057-z

[11] S. Bright, F. Moses, A. Ridout, B. Sam, M. Momoh, V. Goodhart, F. Smart, M. Mannah, S. Issa, S. Herm-Singh, F. Reid, P. T. Seed, J. Bunn, A. Shennan, K. Augustin, and J. Sandall. 2023. Scale-up of a novel vital signs alert device to improve maternity care in Sierra Leone: a mixed methods evaluation of adoption. *Reproductive Health* 20, 1 (2023), 6. https://doi.org/10.1186/s12978-022-01551-2

[12] T. Brown. 2009. *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation.* Harper Collins. https://books.google.com.au/books?id=x7PjWyVUoVAC

[13] R. Brugha and Z. Varvasovszky. 2000. Stakeholder analysis: a review. *Health Policy and Planning* 15, 3 (2000), 239–246. https://doi.org/10.1093/heapol/15.3.239

[14] C. Carmel-Gilfilen and M. Portillo. 2016. Designing With Empathy: Humanizing Narratives for Inspired Healthcare Experiences. *HERD* 9, 2 (2016), 130–46. https://doi.org/10.1177/1937586715592633

[15] D. A. Chambers, R. E. Glasgow, and K. C. Stange. 2013. The dynamic sustainability framework: addressing the paradox of sustainment amid ongoing change. *Implementation Science* 8, 1 (2013), 117. https://doi.org/10.1186/1748-5908-8-117

[16] E. Chen, G. Neta, and M. C. Roberts. 2021. Complementary approaches to problem solving in healthcare and public health: implementation science and human-centered design. *Transl Behav Med* 11, 5 (2021), 1115–1121. https://doi.org/10.1093/tbm/ibaa079

[17] W. Y. Chen, B. Rosner, S. E. Hankinson, G. A. Colditz, and W. C. Willett. 2011. Moderate alcohol consumption during adult life, drinking patterns, and breast cancer risk. *Jama* 306, 17 (2011), 1884–90. https://doi.org/10.1001/jama.2011.1590

[18] Y. J. Choi, S. K. Myung, and J. H. Lee. 2018. Light Alcohol Drinking and Risk of Cancer: A Meta-Analysis of Cohort Studies. *Cancer Res Treat* 50, 2 (2018), 474–487. https://doi.org/10.4143/crt.2017.094

[19] F. L. Cibrian, E. Monteiro, S. E. B. Schuck, M. Nelson, G. R. Hayes, and K. D. Lakes. 2022. Interdisciplinary Tensions When Developing Digital Interventions Supporting Individuals With ADHD. *Front Digit Health* 4 (2022), 876039. https://doi.org/10.3389/fdgth.2022.876039

[20] Bristish Design Council. 2015. What is the framework for innovation? Design Council's evolved Double Diamond. https://www.designcouncil.org.uk/news-opinion/what-framework-innovation-design-councils-evolved-double-diamond.

[21] G. M. Curran, M. Bauer, B. Mittman, J. M. Pyne, and C. Stetler. 2012. Effectiveness-implementation hybrid designs: combining elements of clinical effectiveness and implementation research to enhance public health impact. *Med Care* 50, 3 (2012), 217–26. https://doi.org/10.1097/MLR.0b013e3182408812

[22] A. Daly-Smith, T. Quarmby, V. S. J. Archbold, N. Corrigan, D. Wilson, G. K. Resaland, J. B. Bartholomew, A. Singh, H. E. Tjomsland, L. B. Sherar, A. Chalkley, A. C. Routen, D. Shickle, D. D. Bingham, S. E. Barber, E. van Sluijs, S. J. Fairclough, and J. McKenna. 2020. Using a multi-stakeholder experience-based design process to co-develop the Creating Active Schools Framework. *Int J Behav Nutr Phys Act* 17, 1 (2020), 13. https://doi.org/10.1186/s12966-020-0917-z

[23] L. J. Damschroder and H. J. Hagedorn. 2011. A guiding framework and approach for implementation research in substance use disorders treatment. *Psychol Addict Behav* 25, 2 (2011), 194–205. https://doi.org/10.1037/a0022284 1939-1501 Damschroder, Laura J Hagedorn, Hildi J Journal Article Research Support, U.S. Gov't, Non-P.H.S. Review United States 2011/03/30 Psychol Addict Behav. 2011 Jun;25(2):194-205. doi: 10.1037/a0022284..

[24] L. J. Damschroder, C. M. Reardon, M. A. O. Widerquist, and J. Lowery. 2022. The updated Consolidated Framework for Implementation Research based on user feedback. *Implementation Science* 17, 1 (2022), 75. https://doi.org/10.1186/s13012-022-01245-0

[25] A. R. Dopp, K. E. Parisi, S. A. Munson, and A. R. Lyon. 2020. Aligning implementation and user-centered design strategies to enhance the impact of health services: results from a concept mapping study. *Implementation Science Communications* 1, 1 (2020), 17. https://doi.org/10.1186/s43058-020-00020-w

[26] M. P. Eccles and B. S. Mittman. 2006. Welcome to Implementation Science. *Implementation Science* 1, 1 (2006), 1–1. https://doi.org/10.1186/1748-5908-1-1

[27] L. Evans, J. Evans, C. Pagliari, and . Källander. 2023. Scoping review: exploring the equity impact of current digital health design practices. *Oxford Open Digital Health* 1 (2023), oqad006. https://doi.org/10.1093/oodh/oqad006

[28] F. K. Ferreira, E. H. Song, H. Gomes, E. B. Garcia, and L. M. Ferreira. 2015. New mindset in scientific method in the health field: Design Thinking. *Clinics (Sao Paulo)* 70, 12 (2015), 770–2. https://doi.org/10.6061/clinics/2015(12)01

[29] R. E. Glasgow, S. M. Harden, B. Gaglio, B. Rabin, M. Lee Smith, G. C. Porter, M. G. Ory, and P.A. Estabrooks. 2019. RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review. *Frontiers in Public Health* 7 (2019). https://doi.org/10.3389/fpubh.2019.00064

[30] R. E. Glasgow, T. M. Vogt, and S. M. Boles. 1999. Evaluating the public health impact of health promotion interventions: the RE-AIM framework. *Am J Public Health* 89, 9 (1999), 1322–7. https://doi.org/10.2105/ajph.89.9.1322

[31] I. D. Graham, J. Logan, M. B. Harrison, S. E. Straus, J. Tetroe, W. Caswell, and N. Robinson. 2006. Lost in knowledge translation: time for a map? *J Contin Educ Health Prof* 26, 1 (2006), 13–24. https://doi.org/10.1002/chp.47

[32] C. Granja, W. Janssen, and M. A. Johansen. 2018. Factors Determining the Success and Failure of eHealth Interventions: Systematic Review of the Literature. *J Med Internet Res* 20, 5 (2018), e10235. https://doi.org/10.2196/10235

[33] T. Greenhalgh, H. Maylor, S. Shaw, J. Wherton, C. Papoutsi, V. Betton, N. Nelissen, A. Gremyr, A. Rushforth, M. Koshkouei, and J. Taylor. 2020. The NASSS-CAT Tools for Understanding, Guiding, Monitoring, and Researching Technology Implementation Projects in Health and Social Care: Protocol for an Evaluation Study in Real-World Settings. *JMIR Res Protoc* 9, 5 (2020), e16861. https://doi.org/10.2196/16861

[34] T. Greenhalgh and C. Papoutsi. 2018. Studying complexity in health services research: desperately seeking an overdue paradigm shift. *BMC Medicine* 16, 1 (2018), 95. https://doi.org/10.1186/s12916-018-1089-4

[35] T. Greenhalgh, J. Wherton, C. Papoutsi, J. Lynch, G. Hughes, C. A'Court, S. Hinder, N. Fahy, R. Procter, and S. Shaw. 2017. Beyond adoption: A new framework for

theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. *Journal of Medical Internet Research* 19, 11 (2017). https://doi.org/10.2196/jmir.8775

[36] A. Gremyr, B. Andersson Gäre, T. Greenhalgh, U. Malm, J. Thor, and A. Andersson. 2020. Using Complexity Assessment to Inform the Development and Deployment of a Digital Dashboard for Schizophrenia Care: Case Study. *J Med Internet Res* 22, 4 (2020), e15521. https://doi.org/10.2196/15521

[37] J. Grigg, V. Manning, D. Lockie, M. Giles, R. J. Bell, P. Stragalinos, C. Bernard, C. J. Greenwood, I. Volpe, L. Smith, P. Bragge, and D. I. Lubman. 2023. A brief intervention for improving alcohol literacy and reducing harmful alcohol use by women attending a breast screening service: a randomised controlled trial. *Med J Aust* 218, 11 (2023), 511–519. https://doi.org/10.5694/mja2.51991

[38] J. Grigg, V. Manning, D. Lockie, M. Giles, R. J. Bell, P. Stragalinos, C. Bernard, C. J. Greenwood, I. Volpe, L. Smith, P. Bragge, and D. I. Lubman. 2023. A brief intervention for improving alcohol literacy and reducing harmful alcohol use by women attending a breast screening service: a randomised controlled trial. *Med J Aust* 218, 11 (2023), 511–519. https://doi.org/10.5694/mja2.51991

[39] Christina Harrington, Sheena Erete, and Anne Marie Piper. 2019. Deconstructing Community-Based Collaborative Design: Towards More Equitable Participatory Design Engagements. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 216:1–216:25. https://doi.org/10.1145/3359318

[40] Stefan Holmlid. 2009. Participative, co-operative, emancipatory: From participatory design to service design. In *First Nordic Conference on service design and service innovation*, Vol. 53.

[41] H. F. Hsieh and S. E. Shannon. 2005. Three approaches to qualitative content analysis. *Qualitative Health Research* 15, 9 (2005), 1277–1288. https://doi.org/10.1177/1049732305276687

[42] P. Hyde and H. T. O. Davies. 2004. Service design, culture and performance: Collusion and co-production in health care. *Human Relations* 57, 11 (2004), 1407–1426. https://doi.org/10.1177/0018726704049415 doi: 10.1177/0018726704049415.

[43] T. Jandoo. 2020. WHO guidance for digital health: What it means for researchers. *Digit Health* 6 (2020). https://doi.org/10.1177/2055207619898984

[44] E. F. S. Kaner, F. R. Beyer, C. Garnett, D. Crane, J. Brown, C. Muirhead, J. Redmore, A. O'Donnell, J. J. Newham, F. de Vocht, and et al. 2017. Personalised digital interventions for reducing hazardous and harmful alcohol consumption in community-dwelling populations. *Cochrane Database of Systematic Reviews* 9 (2017). https://doi.org/10.1002/14651858.CD011479.pub2 [Drugs and Alcohol].

[45] K. M. Keyes, J. Jager, T. Mal-Sarkar, M. E. Patrick, C. Rutherford, and D. Hasin. 2019. Is There a Recent Epidemic of Women's Drinking? A Critical Review of National Studies. *Alcohol Clin Exp Res* 43, 7 (2019), 1344–1359. https://doi.org/10.1111/acer.14082

[46] J. A. Kientz, E. K. Choe, B. Birch, R. Maharaj, A. Fonville, C. Glasson, and J. Mundt. 2010. Heuristic evaluation of persuasive health technologies. Association for Computing Machinery, 555–564. https://doi.org/10.1145/1882992.1883084

[47] A. M. Kilbourne, R. E. Glasgow, and D. A. Chambers. 2020. What Can Implementation Science Do for You? Key Success Stories from the Field. *J Gen Intern Med* 35, Suppl 2 (2020), 783–787. https://doi.org/10.1007/s11606-020-06174-6

[48] P. Klasnja, S. Consolvo, and W. Pratt. 2011. How to evaluate technologies for health behavior change in HCI research. Association for Computing Machinery, 3063–3072. https://doi.org/10.1145/1978942.1979396

[49] A. Koh, W. Swanepoel, A. Ling, B. L. Ho, S. Y. Tan, and J. Lim. 2021. Digital health promotion: promise and peril. *Health Promot Int* 36 (2021). https://www.ncbi.nlm.nih.gov/pubmed/34897444

[50] R. Lederman, J. Gleeson, G. Wadley, S. D'alfonso, S. Rice, O. Santesteban-Echarri, and M. Alvarez-Jimenez. 2019. Support for Carers of Young People with Mental Illness: Design and Trial of a Technology-Mediated Therapy. *ACM Trans. Comput.-Hum. Interact.* 26, 1 (2019), Article 4. https://doi.org/10.1145/3301421

[51] M. Lee, H. Lee, Y. Kim, J. Kim, M. Cho, J. Jang, and H. Jang. 2018. Mobile App-Based Health Promotion Programs: A Systematic Review of the Literature. *Int J Environ Res Public Health* 15, 12 (2018). https://doi.org/10.3390/ijerph15122838

[52] M. R. Lennon, M. M. Bouamrane, A. M. Devlin, S. O'Connor, C. O'Donnell, U. Chetty, R. Agbakoba, A. Bikker, E. Grieve, T. Finch, N. Watson, S. Wyke, and F. S. Mair. 2017. Readiness for Delivering Digital Health at Scale: Lessons From a Longitudinal Qualitative Evaluation of a National Digital Health Innovation Program in the United Kingdom. *J Med Internet Res* 19, 2 (2017), e42. https://doi.org/10.2196/jmir.6900

[53] Y. Li, F. M. Li, and P. Carrington. 2023. Breaking the "Inescapable" Cycle of Pain: Supporting Wheelchair Users' Upper Extremity Health Awareness and Management with Tracking Technologies. Association for Computing Machinery, Article 324. https://doi.org/10.1145/3544548.3580660

[54] A. R. Lyon, S. K. Brewer, and P. A. Arean. 2020. Leveraging human-centered design to implement modern psychological science: Return on an early investment. *Am Psychol* 75, 8 (2020), 1067–1079. https://doi.org/10.1037/amp0000652

[55] A. R. Lyon, S. A. Munson, M. Reddy, S. M. Schueller, S. Agapie, S. Yarosh, A. R. Dopp, U. von Thiele Schwarz, G. Doherty, A. K. Graham, K. P. Kruzan, and R. Kornfield. 2023. Bridging HCI and Implementation Science for Innovation Adoption and Public Health Impact. , 7 pages. https://doi.org/10.1145/3544549.3574132

[56] A. R. Lyon, S. A. Munson, B. N. Renn, D. C. Atkins, M. D. Pullmann, E. Friedman, and P. A. Areán. 2019. Use of Human-Centered Design to Improve Implementation of Evidence-Based Psychotherapies in Low-Resource Communities: Protocol for Studies Applying a Framework to Assess Usability. *JMIR Res Protoc* 8, 10 (2019), e14990. https://doi.org/10.2196/14990

[57] A. R. Lyon, J. K. Wasse, K. Ludwig, M. Zachry, E. J. Bruns, J. Unützer, and E. McCauley. 2016. The Contextualized Technology Adaptation Process (CTAP): Optimizing Health Information Technology to Improve Mental Health Systems. *Adm Policy Ment Health* 43, 3 (2016), 394–409. https://doi.org/10.1007/s10488-015-0637-x

[58] S. Mahajan, Y. Lu, E. S. Spatz, K. Nasir, and H. M. Krumholz. 2021. Trends and Predictors of Use of Digital Health Technology in the United States. *The American Journal of Medicine* 134, 1 (2021), 129–134. https://doi.org/10.1016/j.amjmed.2020.06.033

[59] L Mamykina, A. M. Smaldone, S. R. Bakken, N. Elhadad, E. G. Mitchell, P. M. Desai, M. E. Levine, J. N. Tobin, A. Cassells, P. G. Davidson, D. J. Albers, and G. Hripcsak. 2021. Scaling Up HCI Research: from Clinical Trials to Deployment in the Wild. , 6 pages. https://doi.org/10.1145/3411763.3443437

[60] J. S. Marwaha, A. B. Landman, G. A. Brat, T. Dunn, and W. J. Gordon. 2022. Deploying digital health tools within large, complex health systems: key considerations for adoption and implementation. *npj Digital Medicine* 5, 1 (2022), 13. https://doi.org/10.1038/s41746-022-00557-1

[61] S. McHugh, J. Presseau, C. T. Luecking, and B. J. Powell. 2022. Examining the complementarity between the ERIC compilation of implementation strategies and the behaviour change technique taxonomy: a qualitative analysis. *Implementation Science* 17, 1 (2022), 56. https://doi.org/10.1186/s13012-022-01227-2

[62] S. Michie, M. Richardson, M. Johnston, C. Abraham, J. Francis, W. Hardeman, M. P. Eccles, J. Cane, and C. E. Wood. 2013. 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, 1 (2013), 81–95. https://doi.org/10.1007/s12160-013-9486-6

[63] S. Michie, M. van Stralen, and R. West. 2011. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science* 6, 1 (2011), 42–42. https://doi.org/10.1186/1748-5908-6-42

[64] M. Miller, Y. Mojica-Perez, M. Livingston, . Kuntsche, C. J. C. Wright, and S. Kuntsche. 2022. The who and what of women's drinking: Examining risky drinking and associated socio-demographic factors among women aged 40–65 years in Australia. *Drug and Alcohol Review* 41, 4 (2022), 724–731. https://doi.org/10.1111/dar.13428

[65] D. C. Mohr, A. R. Lyon, E. G. Lattie, M. Reddy, and S. M. Schueller. 2017. Accelerating Digital Mental Health Research From Early Design and Creation to Successful Implementation and Sustainment. *J Med Internet Res* 19, 5 (2017), e153. https://doi.org/10.2196/jmir.7725

[66] T. Moir. 2018. Why Is Implementation Science Important for Intervention Design and Evaluation Within Educational Settings? *Frontiers in Education* 3 (2018). https://doi.org/10.3389/feduc.2018.00061

[67] Z. S. Morris, S. Wooding, and J. Grant. 2011. The answer is 17 years, what is the question: understanding time lags in translational research. *Journal of the Royal Society of Medicine* 104, 12 (2011), 510–520. https://doi.org/10.1258/jrsm.2011.110180

[68] G. Neta, L. Martin, and G. Collman. 2022. Advancing environmental health sciences through implementation science. *Environmental Health* 21, 1 (2022), 136. https://doi.org/10.1186/s12940-022-00933-0

[69] P. Nilsen. 2015. Making sense of implementation theories, models and frameworks. *Implementation Science* 10, 1 (2015), 1–13. https://doi.org/10.1186/S13012-015-0242-0/TABLES/2

[70] D. R. Nyatuka and R. de la Harpe. [n. d.]. Evaluating mHealth Interventions in an Underserved Context Using Service Design Strategy: A Case of Kenya *(ICMHI '19)*. Association for Computing Machinery, New York, NY, USA, 153–160. https://doi.org/10.1145/3340037.3340060

[71] Australian Institute of Health and Welfare. 2019. *National Drug Strategy Household Survey 2019*. Report. Australian Institute of Health and Welfare. https://www.aihw.gov.au/getmedia/4f178aedâĂŘ4301âĂŘ4d49âĂŘ8fe6âĂŘc9fa663d914e/aihwâĂŘpheâĂŘ270âĂŘ3âĂŘAlcoholâĂŘtables.xlsx.aspx

[72] J. E. Palacios, A. Enrique, O. Mooney, S. Farrell, C. Earley, D. Duffy, N. Eilert, S. Harty, L. Timulak, and D. Richards. 2022. Durability of treatment effects following internet-delivered cognitive behavioural therapy for depression and anxiety delivered within a routine care setting. *Clinical Psychology and Psychotherapy* 29, 5 (2022), 1768–1777. https://doi.org/10.1002/cpp.2743

[73] I. Pant and A. Poudyal. [n. d.]. Ringingthealarm: Chronic "Pilotitis" Stunts Digital Health in Nepal. In *2019 ITU Kaleidoscope: ICT for Health: Networks, Standards and Innovation (ITU K)*. 1–9. https://doi.org/10.23919/ITUK48006.2019.8996139

[74] D. Paolotti, U. Shah, M. Edelstein, O. Leal Neto, P. Kostkova, and C. Wood. 2019. Digital Health Innovation. , 5-5 pages. https://doi.org/10.1145/3357729.3357764

[75] K. Patrick, E. B. Hekler, D. Estrin, D. C. Mohr, H. Riper, D. Crane, J. Godino, and W. T. Riley. 2016. The Pace of Technologic Change: Implications for Digital Health Behavior Intervention Research. *Am J Prev Med* 51, 5 (2016), 816–824.

https://doi.org/10.1016/j.amepre.2016.05.001

[76] B. J. Powell, T. J. Waltz, M. J. Chinman, L. J. Damschroder, J. L. Smith, M.M. Matthieu, E. K. Proctor, and J. E. Kirchner. 2015. A refined compilation of implementation strategies: results from the Expert Recommendations for Implementing Change (ERIC) project. *Implementation Science* 10, 1 (2015), 21. https://doi.org/10.1186/s13012-015-0209-1

[77] J. Presseau, N. McCleary, F. Lorencatto, A. M. Patey, J. M. Grimshaw, and J. J. Francis. 2019. Action, actor, context, target, time (AACTT): a framework for specifying behaviour. *Implementation Science* 14, 1 (2019), 102. https://doi.org/10.1186/s13012-019-0951-x

[78] E. K. Proctor, B. J. Powell, and J. C. McMillen. 2013. Implementation strategies: recommendations for specifying and reporting. *Implementation Science* 8, 1 (2013), 139. https://doi.org/10.1186/1748-5908-8-139

[79] R. A. Reyneke, I. F. Richens, H. Buchanan, E. Bethan Davies, C. Sorrell, A. Ashmore, and M. L. Brennan. 2023. The use of theories, models, and frameworks to inform the uptake of evidence-based practices in veterinary medicine-a scoping review. *Preventive Veterinary Medicine* 216 (2023), 105928. https://doi.org/10.1016/j.prevetmed.2023.105928

[80] A. M. Roche and V. Kostadinov. 2019. Baby boomers and booze: we should be worried about how older Australians are drinking. *Med J Aust* 211, 8 (2019), 382–382.e1. https://doi.org/10.5694/mja2.50351

[81] E. M Rogers, A. Singhal, and M. M Quinlan. 2008. *Diffusion of innovations*. Routledge, 432–448.

[82] J. Saad-Sulonen, A. de Götzen, N. Morelli, and L. Simeone. 2020. Service design and participatory design: time to join forces? *(PDC '20)*. Association for Computing Machinery, New York, NY, USA, 76–81. https://doi.org/10.1145/3384772.3385133

[83] S.Chatterjee, M. M. Rahman, T.Ahmed, N. Saleheen, E.Nemati, V. Nathan, K. Vatanparvar, and J. Kuang. 2020. Assessing Severity of Pulmonary Obstruction from Respiration Phase-Based Wheeze-Sensing Using Mobile Sensors. Association for Computing Machinery, 1–13. https://doi.org/10.1145/3313831.3376444

[84] J. Shaw, P. Agarwal, L. Desveaux, D. C. Palma, V. Stamenova, T. Jamieson, R. Yang, R. S. Bhatia, and O. Bhattacharyya. 2018. Beyond "implementation": digital health innovation and service design. *npj Digital Medicine* 1, 1 (2018), 48. https://doi.org/10.1038/s41746-018-0059-8

[85] R. C. Shelton, B. R. Cooper, and S. W. Stirman. 2018. The Sustainability of Evidence-Based Interventions and Practices in Public Health and Health Care. *Annual Review of Public Health* 39, 1 (2018), 55–76. https://doi.org/10.1146/annurev-publhealth-040617-014731

[86] J. Sinclair, M. McCann, E. Sheldon, I. Gordon, L. Brierley-Jones, and E. Copson. 2019. The acceptability of addressing alcohol consumption as a modifiable risk factor for breast cancer: a mixed method study within breast screening services and symptomatic breast clinics. *BMJ Open* 9, 6 (2019), e027371. https://doi.org/10.1136/bmjopen-2018-027371

[87] S. E. Slaughter, G. L. Zimmermann, M. Nuspl, H. M. Hanson, L. Albrecht, R. Esmail, K. Sauro, A. S. Newton, M. Donald, M.P. Dyson, D. Thomson, and L. Hartling. 2017. Classification schemes for knowledge translation interventions: a practical resource for researchers. *BMC Medical Research Methodology* 17, 1 (2017), 161. https://doi.org/10.1186/s12874-017-0441-2

[88] L. Stegner, E.Senft, and B. Mutlu. 2023. Situated Participatory Design: A Method for In Situ Design of Robotic Interaction with Older Adults. Association for Computing Machinery, Article 334. https://doi.org/10.1145/3544548.3580893

[89] L. Strifler, R. Cardoso, J. McGowan, E. Cogo, V. Nincic, P. A. Khan, A. Scott, M. Ghassemi, H. MacDonald, Y. Lai, V. Treister, A. C. Tricco, and S. E. Straus. 2018. Scoping review identifies significant number of knowledge translation theories, models, and frameworks with limited use. *J Clin Epidemiol* 100 (2018), 92–102. https://doi.org/10.1016/j.jclinepi.2018.04.008

[90] J. Thomason. 2021. Big tech, big data and the new world of digital health. *Global Health Journal* 5, 4 (2021), 165–168. https://doi.org/10.1016/j.glohj.2021.11.003

[91] M. Tomitsch, C. Wrigley, M. Borthwick, N. Ahmadpour, J. Frawley, A. B. Kocaballi, C. Nunez-Pascheco, K. Straker, and L. Loke. 2018. *Design. Think. Make. Break. Repeat: a handbook of methods*. Bis Publishers, Amsterdam.

[92] M. van Limburg, J.E. W. C. van Gemert-Pijnen, N. Nijland, H. C. Ossebaard, R.M. G. Hendrix, and E. R. Seydel. 2011. Why Business Modeling is Crucial in the Development of eHealth Technologies. *J Med Internet Res* 13, 4 (2011), e124. https://doi.org/10.2196/jmir.1674

[93] B. J. Weiner. 2009. A theory of organizational readiness for change. *Implementation Science* 4, 1 (2009), 67. https://doi.org/10.1186/1748-5908-4-67

[94] M. Wensing and P. Wilson. 2023. Making implementation science more efficient: capitalizing on opportunities beyond the field. *Implementation Science* 18, 1 (2023), 40. https://doi.org/10.1186/s13012-023-01298-9

[95] S. Wiltsey Stirman, A. A. Baumann, and C. J. Miller. 2019. The FRAME: an expanded framework for reporting adaptations and modifications to evidence-based interventions. *Implementation Science* 14, 1 (2019), 58. https://doi.org/10.1186/s13012-019-0898-y

[96] D. Wolstenholme, C. Grindell, and A. Dearden. 2017. A co-design approach to service improvement resulted in teams exhibiting characteristics that support innovation. *Design for Health* 1, 1 (2017), 42–58. https://doi.org/10.1080/24735132.2017.1295531

[97] X. Zhou, M. S. Ackerman, and K. Zheng. 2010. Doctors and psychosocial information: records and reuse in inpatient care. Association for Computing Machinery, 1767–1776. https://doi.org/10.1145/1753326.1753592