



Ensuring Patient Safety through Digital Health Technologies

by
Lilja Guðrún Jóhannsdóttir

Dissertation submitted to the School of Computer Science
at Reykjavík University in partial fulfillment
of the requirements for the degree of

Doctor of Philosophy

22nd of April, 2025

Thesis Committee:

Anna Sigríður Islind, Primary supervisor
Professor, Reykjavík University, Iceland

María Óskarsdóttir, Co-supervisor
Associate Professor, Reykjavík University, Iceland

Marta Kristín Lárusdóttir, Committee member
Professor, Reykjavík University, Iceland

Berglind Guðmundsdóttir, Committee member
Professor, University of Iceland

Daniel Fürstenau, Examiner
Professor, Freie Universität Berlin, Germany

© Lilja Guðrún Jóhannsdóttir
22nd of April, 2025

ISBN 978-9935-539-74-8 Print version
ISBN 978-9935-539-75-5 Electronic version
ORCID 0000-0002-2076-3289
Copyright ©2025 Lilja Guðrún Jóhannsdóttir

This work is licensed under the Creative Commons Attribution-NonCommercial- NoDerivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>). You may copy and redistribute the material in any medium or format, provide appropriate credit, link to the license and indicate what changes you made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. You may not use the material for commercial purposes. If you remix, transform or build upon the material, you may not distribute the modified material. The images or other third party material in this thesis are included in the book's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the book's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Ensuring Patient Safety through Digital Health Technologies

Lilja Guðrún Jóhannsdóttir

April 22nd, 2025

Abstract

Patient safety is a core objective in healthcare, aiming to minimize risks, prevent avoidable harm, reduce errors, and mitigate the impact of adverse events. While some errors are easily identifiable, others require retrospective analysis to determine their consequences for specific patient groups. Patient safety is often discussed alongside quality of care, as both involve reducing harm and improving healthcare outcomes. Beyond being a fundamental goal, patient safety is a discipline that applies safety science to healthcare delivery. Safety science integrates engineering, psychology, human factors, risk management, and organizational behavior to improve systems, technologies, and human behavior, ultimately enhancing safety and reducing hazards.

This thesis explores how digital health technologies can enhance patient safety, focusing on the National Hospital of Iceland's digital health platform. The platform includes web and mobile applications for healthcare professionals and patients, integrating third-party solutions to modernize healthcare, streamline workflows, and improve access to patient data. A co-design approach involving healthcare professionals and patients has been used in its development, ensuring user needs are addressed. The effectiveness of medical treatments relies heavily on human behavior. The decision-making of both healthcare professionals and patients can be influenced by their environments, and even minor changes in how information is presented can significantly affect these user groups' behavior. The concept, known as "choice architecture," includes the use of "nudges" to guide decisions without restricting options. In healthcare, framing user interface design choices, such as physician recommendations for vaccines or default settings in electronic health records for prescriptions, can greatly impact treatment choices. As healthcare becomes increasingly digital, digital nudging offers a valuable tool for improving

patient safety.

This thesis examines digital nudging from the perspective of digital health platform designers working closely with healthcare professionals. While prior research has highlighted how digital nudges benefit patient care, there is limited exploration of how these nudges are designed and developed to enhance patient safety. The research is based on five papers that analyze different aspects of digital health technologies. Paper P1 investigates how the introduction of a mobile app for bedside documentation supports patient safety. Paper P2 examines how data collection through digital tools can improve quality of care, particularly for patients with atrial fibrillation before and after surgery. Paper P3 shifts focus to patients with inflammatory bowel diseases, exploring how a digital health program influences health outcomes and literacy. Paper P4 systematically reviews digital nudges in healthcare, assessing their impact on treatment and patient management. Paper P5 explores user perceptions of digital nudges and develops design guidelines for their ethical implementation.

To study the various aspects of digital health technologies incorporated into the National Hospital digital health platform and how they contribute to patient safety we adopt both qualitative and quantitative methods. For our research design, we have strategized to use empirical data from the National Hospital to answer the research question. We apply standard usability questionnaires to measure the views of the healthcare professionals, and to measure the impacts of the design features we compare usage of the healthcare professionals before and after the features were deployed. The thesis (i) examines five themes that can contribute to the design and development of DHTs that ensure patient safety (ii) presents six dimensions that can contribute to patient safety in the design of DHTs, and (iii) presents a model that conceptualizes socio-technical key elements of patient safety. Together, the findings contribute to the discourse of digital health platforms in the information system literature with the conceptualization of the examination of a continuous co-design process.

Keywords: Patient Safety, Digital Health Technologies, Socio-technical Systems Theory, Digital Nudging

Acknowledgements

Curiosity first brought me to the Department of Computer Science at Reykjavík University, a few years ago, while I was expecting my eldest son. Now, as I prepare to welcome our fifth child into the world, I find myself reflecting on a journey that has been shaped not only by academic pursuit but by life itself in all its complexity and beauty.

My deepest gratitude goes to my husband, Jón Pétur Guðmundsson, whose unwavering love, care, and support have made this journey possible. He has been my anchor, my constant, and the quiet strength behind so much of what I have accomplished. I am also profoundly thankful to all those who helped care for our children and offered encouragement along the way, your kindness and generosity made a world of difference.

As my research progressed, patient safety emerged as the central theme of this thesis during the process of synthesis and reflection. In truth, it was always there, an enduring concern that flows from societal values through healthcare systems and into the hands of every individual who delivers care. Patient safety is more than a professional objective; it is a moral imperative. Every adverse event in healthcare is not just a statistic but a deeply human experience, one that can leave lasting scars on patients and their loved ones.

This work is dedicated to my daughter, born and passed away in Madrid, Spain, on May 2nd 2017. Her brief presence in this world continues to resonate in my life and in the values that underpin this thesis. Her memory has been a quiet guide, reminding me always of the human stakes behind the data, the systems, and the work we do.

Publications List

Publications Included in The Thesis

Publication I

Jóhannsdóttir, L. G., Snorradóttir, A. H. N., Tracz, A., Óskarsdóttir, M., Islind, A. S. (2025). Co-Designing Digital Health Applications: Unravelling the Importance of Mobile Bedside Documentation Practices. In *Proceedings of Americas Conference of Information Systems*

Publication II

Jóhannsdóttir, L. G., Erlingsdóttir, H. Ý., Kristjánsdóttir, H., Jónsson, B., Óskarsdóttir, M., Islind, A. S. (under review) Improved Healthcare Delivery Process for Patients with Atrial Fibrillation: Design Principles and a Novel Digital Health Platform. Under review at *Health Informatics Journal*

Publication III

Oddsson, S. J., Gunnarsdóttir, T., **Jóhannsdóttir, L. G.**, Amundadóttir, M. L., Frimannsdóttir, A., ... and Thorgeirsson, T. (2023). A new digital health program for patients with inflammatory bowel disease: preliminary program evaluation. *JMIR Formative Research*, 7(1), e39331.

Publication IV

Jóhannsdóttir, L. G., Sigurðardóttir, S. G., Óskarsdóttir, M., Islind, A. S. (forthcoming). Digital Nudging in Digital Health Technologies: A Systematic Review. Accepted with minor revision in *Health and Technology*

Publication V

Jóhannsdóttir, L. G., Visesco, I., Lárusdóttir, M. K., Óskarsdóttir, M., Islind, A. S. (forthcoming). Two sides of Persuasive System Design: Understanding Digital Nudging and Dark Patterns and its Impact on Teenage Girls. Accepted with minor revision in *Behaviour and Information Technology*

Other Publications by Author

Visescu, I., **Jóhannsdóttir, L. G.**, Islind A. S., (2024) Whistling in the Dark: Inability to Recognize Dark Patterns and Lack of Concern Amongst Teenagers. *In Proceedings of the Italian Chapter of AIS (Association for Information Systems), AISel*

List of Tables

2.1	Common examples of cognitive biases and heuristics that can be exploited to promote behavior or attitudinal change.	19
3.1	Overview of DHTs and artifacts of the National Hospital digital health platform	27
3.2	Participants per data gathering method in the included studies 1-5	32
3.3	Declaration of authorship contribution	40

List of Figures

2.1	Based on a patient safety model for healthcare from Emanuel et al. 2009	9
3.1	Patient safety model based on Emanuel et al. 2009 and Carayon et al. 2020	24
3.2	Overview of the components of the National Hospital digital health platform	26
3.3	The Action Design Research phases of the National Hospital digital health platform and the position of the studies 1-5 within it	29
3.4	Venn diagram showing the themes that also reflect the five studies	33
3.5	Data collection with three custom-develop questionnaires for study 5	38
4.1	How each study relates to a simplified patient safety model	42
4.2	Data collection through the AF patient journey . .	46
6.1	Stages of change (Prochaska and Velicer, 1997) . .	72
6.2	A proposed revised model of patient safety	75

Contents

Abstract	iii
Acknowledgements	v
List of Tables	viii
List of Figures	ix
1 Introduction	1
2 Theoretical Background	7
2.1 Patient Safety	7
2.2 Digital Health Technology	11
2.3 Digital Transformation and Co-Design	14
2.4 Digital Nudging in DHTs	16
3 Research Approach	23
3.1 Overview of the Research Project	23
3.2 Empirical Context	25
3.3 Action Design Research	28
3.4 Data Gathering and Analysis	30
3.5 Studies Conducted	32
3.5.1 Study 1: Digital Transformation for Bed-side Documentation	34
3.5.2 Study 2: Continuous Quality Improvements for Healthcare Delivery	35
3.5.3 Study 3: Evaluation of Patient Engagement and Patient Outcomes	35
3.5.4 Study 4: Systematic Review of Digital Nudging in Healthcare Settings	36
3.5.5 Study 5: Guidelines for Teaching and Learning about Design	37
3.6 The Researcher Role	39

4	Results	41
4.1	Making Sense of the Results	41
4.2	Paper: 1	42
4.3	Paper: 2	45
4.4	Paper: 3	48
4.5	Paper: 4	50
4.6	Paper: 5	52
5	Synthesis	57
5.1	The Themes for Patient Safety	58
5.2	Dimensions in Design	62
6	Discussion	67
6.1	RQ: How can DHT improve patient safety?	68
6.2	Patient Safety and Usability	70
6.3	Practical Contribution	71
6.3.1	Practical Guidelines for Patient Safety through DHTs	71
6.3.2	Influencing Behavior and Attitudes to Im- prove Patient Safety	72
6.4	Theoretical Contribution	74
6.4.1	An Extension to a Patient Safety Model . .	75
6.4.2	Implications for Healthcare Policy	76
6.5	Limitations and Future Work	77
7	Conclusion	79
	Bibliography	81
A	Publications	99
B	Paper 1	101
C	Paper 2	113
D	Paper 3	125
E	Paper 4	141
F	Paper 5	163

Chapter 1

Introduction

Each year, millions suffer or die from unsafe healthcare, posing a global challenge, especially in low- and middle-income countries. In these regions, 134 million hospital-related adverse events occur annually, leading to 2.6 million deaths. Even in high-income nations, one in ten patients experience harm during hospital care. The social cost of patient harm is staggering, ranging from 1-2 trillion each year (WHO, 2021). Patient safety refers to a “framework of organized activities that creates cultures, processes, procedures, behaviors, technologies, and environments in healthcare that consistently and sustainably lower risks, reduce the occurrence of avoidable harm, make errors less likely, and reduce the impact of harm when it does occur” (WHO, 2021). As a fundamental goal in healthcare, patient safety aims to ensure continuous quality improvements ultimately protecting lives and improving patient outcomes (Vincent, 2011). Beyond being a core objective in healthcare, patient safety is a discipline rooted in applying safety science to healthcare delivery to provide safe, effective, and efficient care. Safety science integrates principles from engineering, psychology, human factors, risk management, and organizational behavior to understand and mitigate risks (Vincent, 2011). It focuses on improving systems, technologies, and human behavior to enhance safety and reduce hazards, analyze adverse events, design safer processes, and develop regulations and best practices to create safer environments (Li et al., 2021). Measuring patient safety is challenging because it may rely on the reporting of mistakes and adverse events that could have been avoided (McDonald et

al., 2010). Reflecting on whether the number of adverse events is high or low is difficult, for example, because one department could hardly ever report any adverse event for two reasons. On the one hand, because they very rarely occur, or on the other hand because the culture in that department does not adequately support reporting of adverse events. Furthermore, only a fraction of the reported adverse events that happen in the healthcare sector are related to digital health technologies.

The integration of digital health technology (hereinafter DHTs) has become more prevalent in the healthcare industry, revolutionizing the way patient care is delivered (Mahajan et al. 2021; Oddsson et al. 2022). DHTs refer to the use of digital platforms, connected sensors, and mobile applications to enhance patient lives and work within healthcare settings (Sharma et al. 2018). The information infrastructure in healthcare often consists of large heavyweight digital infrastructure constellations that are becoming increasingly complex and rigid, requiring extensive time and effort to facilitate change and to meet the needs of innovation (Ellingsen 2024; Severinsen et al. 2022). Increasingly, lightweight IT applications, complementary to the existing heavyweight digital infrastructure, are entering the e-health field. These innovative and frequent iterations support immediate user needs and work processes, with simple applications like apps (Bygstad 2017). With the rise of DHTs and lightweight IT, healthcare professionals are presented with new opportunities to streamline workflows, enhance the quality of care, and improve overall efficiency within clinical settings (Rosenlund et al. 2023). However, with these developments come unique challenges and considerations concerning patient safety, usability, functionality, and integration of lightweight IT with existing healthcare practices (Yeung et al. 2023; Giebel et al. 2023). Usability is the extent to which a system can be used by specified users, in our case patients or healthcare professionals, to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO-standard, 2018). Digital health technologies bridge the gap between patients and healthcare by enabling digital platforms that collect and visualize patient health data (Islind, 2018). The adoption and use of these platforms are becoming increasingly widespread and established in healthcare (Islind, 2018).

With the rise of DHTs, their impact on patient safety and healthcare professionals is becoming increasingly significant (Math-

ews et al., 2019). Digital health technologies such as electronic health records (EHRs), telemedicine, and clinical decision support systems help healthcare professionals enhance patient safety and improve health outcomes (Emanuel et al., 2009). However, ensuring data accuracy and protection against breaches, as errors or data loss can have serious consequences (Sujan et al, 2019). The growing integration of DHTs is reshaping the role of healthcare professionals within the healthcare trajectory. These technologies not only improve patient safety but also protect healthcare professionals from disputes or malpractice claims by providing evidence of the care provided, as a legal record (Sharifi et al., 2021). Central to this thesis is an exploration of the role of digital health technology in enhancing patient safety and its implications for healthcare professionals and organizations. The area of healthcare quality and patient safety is starting to use digital health technologies to prevent adverse events, identify them before they become issues, and act on events that are thought to be unavoidable (Feldman et al., 2018). Redesigning systems and processes can significantly minimize errors and incorporating design approaches such as standardization, simplification, and constraints can effectively reduce mistakes (Emanuel et al., 2009). An example of a constraint is a “forcing function”, a design element that eliminates the possibility of error. For instance, incompatible connectors prevent an anesthetic gas from being attached to the oxygen port of an anesthesia machine (Emanuel et al., 2009). These design methods can be transferred to a digital environment and the designs of those technologies must be sensible to the cognitive strategies employed by healthcare professionals (Lintern and Motavalli, 2018).

Sometimes adverse events are obvious such as the downtime of DHTs (Harrison et al., 2019). Other times they are less apparent and rely more heavily on human behavior. Regardless of how effective a drug, vaccine, or therapy might be, its health benefits typically depend on a healthcare professionals’ prescription and a patient’s adherence to the treatment plan. To encourage the desired behavior, DHTs must be designed in a way that makes it easy to do the right thing, and for DHTs to be well-designed co-design is essential. It is the merging of the efforts of those who produce and those who use the solutions to address these challenges and health problems. Co-design is a collaborative design approach that actively involves stakeholders, including users and community members, in the design process (Grindell et al.,

2022). It emphasizes their perspectives and experiences, fostering a sense of ownership and ensuring that outcomes meet their needs. Socio-technical system theory highlights the interplay between social and technical factors within organizations (Ropohl, 1999). It suggests that successful systems must consider both human and technological components. When combined, co-design and socio-technical system theory create a framework for developing solutions that are both user-centered and contextually relevant, leading to enhanced usability and more sustainable outcomes in diverse environments.

The environments of both healthcare professionals and patients can influence and shape their decision-making, and even small changes in how information and options are presented can significantly impact behavior. Within digital health, there is growing interest in how DHTs can be designed so that the choices that they include are accurately and thoughtfully presented (Lintern and Motavalli, 2018). When this “choice architecture” is structured to guide behavior in a predictable manner without limiting options, it is commonly referred to as a “nudge” (Thaler and Sunstein, 2008). In healthcare, critical information and significant decisions are continuously being presented. This could be how a physician recommends an influenza vaccine or how the treatment duration is set as default for a new opioid prescription in EHRs. However, these default settings are often chosen randomly, without considering the common objectives of overcoming vaccination barriers or managing the trade-off between pain relief and the risk of addiction (Patel et al. 2018). Healthcare offers many opportunities for effective nudges, as choice architectures influence our behavior, often without our awareness (Halpern et al. 2007). Nudges exist in the physical environment such as those that increase hand sanitizer use at hospitals (Mobekk and Stokke, 2020), but they also exist in the digital environment. With more healthcare decisions taking place in digital health technologies where actions can be observed and the context can be easily adjusted, the potential for digital nudging increases. Digital nudging is an approach where people’s cognitive biases are actively used and applied to the design elements in the user interface (UI) to affect the choices of users in digital health technologies (Mirsch et al. 2017; Schneider et al. 2018).

DHTs allows for scalable and readily available solutions for patients and healthcare professionals, and digital nudging can be

embedded within those. A recent systematic review focused on digital nudges that influence healthcare professionals toward giving treatment in line with treatment guidelines (Nwafor et al. 2021). In their assessment, they found compelling evidence that nudges are an effective tool for promoting adherence to guidelines. They also observed that the literature is primarily focused on whether nudge interventions work, with little consideration for organizational issues such as cost-effectiveness, impact on healthcare professionals, and disruptions of established workflows and routines (Nwafor et al. 2021). Digital nudging is a powerful tool for designers of digital choice environments because people are subconsciously influenced in their decisions. Responsibility allows us to evaluate transformational digital technologies and the use of digital nudges in a balanced manner, by factoring in both harmful and positive outcomes from the engagement with such artifacts (Voegtlin et al., 2022). A systematic approach to designing digital nudges, considering responsibility and ethics, should be the guiding light for designers when designing user interfaces, choice architecture, and digital services in general.

DHTs cannot be evaluated without considering the impact on the organizations where they are being implemented, with a specific focus on digital transformation that is rapidly changing the work environment for healthcare professionals. Digital transformation is the process of integrating digital technologies into all aspects of an organization, fundamentally changing how healthcare professionals operate and deliver value to patients (Kraus et al. 2021). This transformation often involves a cultural shift that requires healthcare professionals to challenge the status quo, experiment, and get comfortable with failure. The National Hospital has integrated its digital infrastructure for clinical support, such as electronic patient systems, lab, imaging, and surgical systems, into an integration layer. On top of that integration layer, the hospital has developed a digital health platform including a web application for healthcare professionals, a mobile application for healthcare professionals, and a mobile application for patients. In addition to that, there are a few 3rd party solutions for patients, developed by independent entities, and integrated into the digital infrastructure. In a hospital such as the National Hospital that operates almost 80 clinical departments, where just over 600 patients are receiving care every day in inpatient departments and around 1700 patients visit outpatient departments every weekday,

there are around 10-20 adverse events reported daily.

Drawing from the experience of designing and developing features in the National Hospital digital health platform, this thesis highlights some of the learnings, challenges, and opportunities in ensuring patient safety through digital health technologies through the insights gained from five papers. To answer the main research question: How can digital health technologies improve patient safety? Paper P1 examines how the digital transformation of introducing the National Hospital mobile application for healthcare professionals, in combination with an electronic whiteboard, as a new approach for bedside documentation practices can support patient safety. Papers P2 explores how data collection through DHTs throughout a patient's journey can lay the foundation of patient safety and improvements in quality of care. We focused on patients with atrial fibrillation heart condition before and after they go through surgery at the National Hospital. In the first two papers, we examine healthcare professionals as users of the digital health platform. However, in paper P3 we evaluate the digital health program of Sidekick Health from the viewpoint of patients with inflammatory bowel diseases. Here we investigate how a digital health program can influence patient outcomes, and behavior that align with patient safety. Paper P4 offers a systematic review of digital nudges in DHTs in various healthcare settings and their effectiveness in supporting patient treatment, safety, and management. Finally, paper P5 addresses user understanding of digital nudges and attitudes towards the usage of digital nudges. In paper P5, design guidelines were developed for designers and educators to guide the ethical usage of digital nudges when designing and developing digital technologies.

In this action design research project, in collaboration with the National Hospital and Sidekick Health, we explore how DHT within healthcare settings supports patient safety. The platforms were under further development through a co-design approach with healthcare professionals. The main contribution of the thesis to the field of information systems in general, and to the approaches to design, development, and use of DHTs in particular is: (i) in-depth knowledge of approaches in which digital health technologies can be utilized to support patient safety, and (ii) practical guidelines which can guide others in their design and development of digital health technologies when working with digital health platforms on patient safety improvements.

Chapter 2

Theoretical Background

In this chapter, I will introduce patient safety, digital health technology, digital transformation and co-design, and digital nudging in digital health technologies.

2.1 Patient Safety

Every year, large numbers of patients are harmed or die because of unsafe healthcare, creating a high burden of death and disability worldwide, especially in low- and middle-income countries. Available evidence suggests that 134 million adverse events due to unsafe care occur in hospitals in low- and middle-income countries, contributing to around 2.6 million deaths every year (WHO, 2021). On average, an estimated one in ten patients is subject to an adverse event while receiving hospital care in high-income countries (WHO, 2021). According to recent estimates, the social cost of patient harm can be valued at 1-2 trillion dollars a year (WHO, 2021). Patient safety is defined by the World Health Organization (WHO) as follows: “*A framework of organized activities that creates cultures, processes, procedures, behaviors, technologies and environments in healthcare that consistently and sustainably lower risks, reduce the occurrence of avoidable harm, make errors less likely and reduce the impact of harm when it does occur*” (WHO, 2021). Digital transformation is revolutionizing patient safety by harnessing technologies and data analytics to refine processes, boost communication, and minimize errors in healthcare delivery (Stoumpos et al., 2023). Vast amounts of data are

generated daily in healthcare that is marked by high stakes and the complexities of hospital systems (Pedersen and Bossen, 2024). Leveraging this digitally captured data for continuous quality improvement is a powerful way to enhance patient safety (Sheikh et al., 2021). Additionally, empowering patients to take control of their health information fosters engagement and contributes significantly to safety outcomes (Esmaeilzadeh et al., 2024). When patients receive feedback on their care plans and health progress, they are more likely to adopt healthier behaviors that lead to better health outcomes and increased patient safety (Meske et al., 2019; Purohit et al., 2023). Finally, training healthcare professionals is essential for ensuring patient safety, with teamwork (Alsabri et al., 2022) and innovative educational approaches (Dahalan et al., 2024) playing a crucial role in the design and development of DHTs. Patient safety is a discipline in the healthcare sector that applies safety science methods toward the goal of achieving a trustworthy system of healthcare delivery. Patient safety is also an attribute of healthcare systems; it minimizes the incidence and impact of and maximizes recovery from adverse events (Emanuel et al., 2009).

Patient safety has developed by considering limiting blame, systems thinking, accountability for delivering effective safe care, and emphasizing teamwork (Emanuel et al. 2009). The following simple model with which to view patient safety divides healthcare systems into four main elements: (i) patients, (ii) healthcare professionals, (iii) systems for therapeutic action, and (iv) continuous quality improvement. These four elements are represented graphically in the figure below. Each element interacts with the other element and with the environment, as depicted by the dotted lines between them and at their outer edges. The result is a core, overarching model for patient safety (Emanuel et al. 2009). First, the patients are the people who receive healthcare or have a stake in its availability. Here we also consider the patient's characteristics. Second, healthcare professionals refer to the people who work in the healthcare system, the team factors as well as the individual factors. Third, systems of therapeutic actions refer to technology, the organization and management, the work environment, task factors, and the external environment. Finally, the continuous quality improvements represent system knowledge, understanding of variations, understanding of how change yields knowledge and psychology. What we see from this simple model is

that patient safety includes many elements. Thus, the irreducible unit of patient safety delivery is multifaceted; all components of healthcare delivery must be integrated into a system that is as reliable as possible under complex conditions.

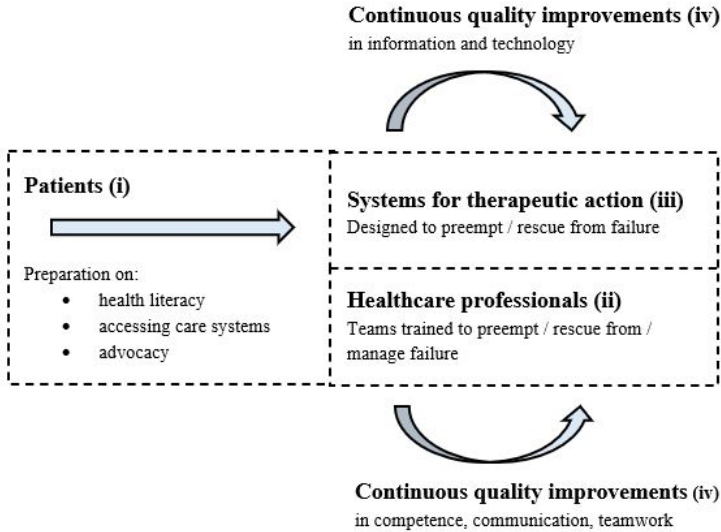


Figure 2.1: Based on a patient safety model for healthcare from Emanuel et al. 2009

The fundamental mechanism for achieving patient safety is through high-reliability design, which is an approach to design that minimizes errors, enhances safety, and ensures consistent, high-quality performance, even in complex or high-risk environments (Weick and Sutcliffe, 2015). A distinctive aspect of high-reliability design is rooted in complexity theory, which recognizes that open, interacting systems naturally generate some level of chaos or inherently unpredictable events (Turner and Baker, 2019). High-reliability designs, however, are built to be resilient, enabling systems to maintain functionality even in the face of such unexpected occurrences (Weick and Sutcliffe, 2015). The unique characteristics of high-reliability organizations have attracted a great deal of attention from the patient safety community, as they offer valuable insights into improving reliability and resilience in healthcare systems. Human factors play a crucial role in devel-

oping high-reliability and resilient healthcare systems and organizations (Weick and Sutcliffe, 2015). One of the most significant differences between healthcare and other high-risk industries is the emphasis on human factors to understand how safety issues arise and how this knowledge can be used to build system defenses, ultimately making them more resilient to accidents and adverse events. The human factors approach is multidisciplinary and integrative, focusing on individuals within a socio-technical context (Ropohl, 1999). In healthcare, this perspective considers both healthcare professionals within their work environment and patients within their care journey. Resilient and equitable healthcare systems demonstrate a strong focus on human factors, ensuring that processes and environments support safety and efficiency (WHO, 2021). In contrast, a lack of attention to human factors is characteristic of rigid or error-prone systems and is a common contributor to adverse events in healthcare (Jabin et al., 2024). Although healthcare leaders and managers have long recognized the potential benefits of adopting a human factors approach, particularly in improving patient safety, actual implementation of human factors principles remains limited in scale (WHO, 2021). The reasons are organizational resistance to change as healthcare systems are traditionally hierarchical and complex, making it difficult to integrate new approaches, especially those that require changes in workflow, culture, and infrastructure (Cheraghi et al., 2023). Also, there is limited access to awareness and training, as many healthcare professionals are not formally educated in human factor science, leading to a lack of understanding of its principal applications (Sheehan et al., 2022).

Another model for patient safety is the System Engineering Initiative for Patient Safety (SEIPS) (Carayon et al. 2020). In the SEIPS 3.0 model, which is a socio-technical system approach to patients' journey and patient safety the components are similar to those in Emanuel et al. 2009 model and include (i) patients (including caregivers), (ii) healthcare professionals, (iii) work systems (tools and technology, tasks, physical environment, and organizational conditions), and (iv) adaption, learning, improvement (Beleffi et al. 2021). The socio-technical systems approach considers that human factors emphasize the need to design a hierarchy of action systems that considers multiple levels (Ropohl, 1999): the micro level of the patient; the meso level of the interaction between individuals in organizations (healthcare facilities and services);

and the macro level of the society (government). This is a useful approach to consider at all levels when integrating new technology or strategies such as patient safety. The human factors approach goes beyond focusing solely on the individuals within the system to also account for the environment, the surrounding physical settings, and critical elements such as procedures, artifacts, safety checks, teamwork, risks, organizational culture, and structure, as well as national regulations and policies. For a system to be resilient and enhance safety, the consideration and integration of all these elements are essential (Weick and Sutcliffe, 2015). Building and maintaining a strong patient safety-oriented culture requires dedicated leadership at every level of the action system, within ministries of health, healthcare facilities, and clinical teams. The principles of socio-technical systems theory and high-reliability organizations are prominently reflected in the “WHO Global Patient Safety Action Plan 2021–2030” (WHO, 2021). These guiding principles integrate the essential elements of human factors across all healthcare settings, with the goal of eliminating avoidable harm in healthcare. Furthermore, these principles are underpinned by values designed to inform the development and implementation of patient safety practices worldwide. WHO guiding principles for patient safety 2021 – 2030 are 8 and are the following: (1) engage patients and families as partners in safe care, (2) achieve results through collaborative working, (4) analyze and share data to generate learning, (5) translate evidence into actionable and measurable improvement, (6) base policies and action on the nature of the care setting, (7) use both scientific expertise and patient experience to improve safety, (8) instill a safety culture in the design and delivery of healthcare. Patient safety needs to be evaluated based on different domains and multiple levels, considering different roles and the interplay between sociology and technology.

2.2 Digital Health Technology

Digital health technologies encompass a wide range of tools, systems, and applications that use digital technology to enhance healthcare delivery, improve patient outcomes, and streamline medical processes (Islind, 2018). They leverage advancements in digital technology like mobile apps, communication tools, wearable devices, and analytics to revolutionize healthcare for patients,

providers, and organizations. One of the most significant developments in digital health technology is telemedicine, which allows patients to consult healthcare professionals remotely via digital health platforms, reducing geographic barriers and improving access to care (Haleem et al. 2021). Similarly, tools like wearable devices like fitness trackers, smartwatches, and medical-grade biosensors enable continuous health monitoring, offering real-time data on vital signs, physical activity, sleep patterns, and more (Haleem et al. 2021). Mobile apps allow individuals to manage chronic conditions, track medications, or access personalized wellness programs (Masoumian Hosseini et al. 2023). Scanning and tracking technologies have also demonstrated how technologies can yield measurable safety benefits by scanning patients' wristbands before clinical documentation or administering medication (Flott et al. 2021). Implementing scanning and tracking protocols consistently across several hospitals in the United Kingdom demonstrated a reduction in patient identification errors and never events, whilst also improving traceability of devices and facilitating product recalls when required (GS1 UK, 2020). Never event refers to a serious, preventable medical error that should never happen if proper safety protocols are followed. During the implementation in the United Kingdom one pharmacy department found the scanning technologies reduced error rates by up to 76 percent (GS1 UK, 2020). Furthermore, in the United Kingdom scanning technologies helped free up time for patient care, equivalent to adding 16 nurses per organization, as well as saving each organization £2.75m per year (Flott et al. 2021). Digital health technologies also enhance public health by enabling data aggregation for research, outbreak tracking, and policymaking (Masoumian Hosseini et al. 2023). However, challenges such as data privacy, accessibility disparities, and the need for regulatory oversight remain critical. Despite these obstacles, digital health technologies hold transformative potential to make healthcare more accessible, efficient, and patient-centered.

Patient engagement refers to the active involvement of patients in their healthcare journey, fostering collaboration between individuals and healthcare providers to improve health outcomes, satisfaction, and quality of care (Hickmann et al. 2022). It emphasizes empowering patients with the knowledge, tools, and resources necessary to make informed decisions about their health and manage their conditions effectively (Hickmann et al. 2022).

Engaged patients are more likely to adhere to treatment plans, attend follow-up appointments, and adopt healthier behaviors, all of which contribute to better outcomes (Farrall et al. 2023). Healthcare providers play a critical role in promoting engagement by building strong relationships, encouraging open communication, and guiding patients to take an active role in their care (Muscat et al. 2021). Shared decision-making, where patients and healthcare professionals work together to make healthcare choices, is central to this process (Muscat et al. 2021). Digital technology has revolutionized patient engagement, offering tools like mobile apps, wearable devices, and communication tools. Together these tools provide a platform to access health records, appointment scheduling, medication reminders, and personalized health education, enabling patients to stay connected and informed (Muscat et al. 2021). However, challenges such as digital literacy gaps, socioeconomic inequalities, and data privacy concerns must be addressed to ensure equitable engagement (McCaffery et al. 2010). Fostering a culture of partnership and leveraging technology effectively patient engagement can transform healthcare into a more patient-centered and collaborative model (Muscat et al. 2021).

Health analytics refers to the use of digital tools, technologies, and methodologies to analyze patient information and generate actionable insights for improving healthcare outcomes (Khalifa and Zabani, 2016). By leveraging electronic health records (EHRs), wearable devices, and algorithms, health analytics play a pivotal role in enhancing patient safety in several ways. One key benefit is the early detection of risks (Khalifa, 2018). Predictive analytics can identify patterns in patient data, such as vital signs, lab results, or medication history, to foresee complications like infections, sepsis, or adverse drug reactions (Khalifa, 2018). This allows healthcare professionals to intervene proactively and prevent harm. Similarly, analytics can monitor adherence to treatment protocols, ensuring consistent and safe care delivery. Healthcare analytics enhances hospital workflows by identifying system inefficiencies and bottlenecks, reducing miscommunication during care transitions (Islam, 2018). Healthcare analytics fosters a data-driven approach to care, that can significantly reduce risks, increasing accountability, and ultimately ensuring patient safety (Islam, 2018).

2.3 Digital Transformation and Co-Design

The notion of integrating digital technology into organizations, fundamentally changing how they operate and adapt to an increasingly digital world is called digital transformation (Kraus et al. 2021). This process goes beyond simply adopting new DHT; it involves reshaping mindsets, workflows, and processes to leverage technology effectively (Kraus, 2021). At its core, digital transformation in healthcare seeks to improve efficiency, drive innovation, and enhance patient and healthcare professionals' experiences and engagement (Lane, 2011). Organizations can analyze data from the users of DHTs to analyze user needs and offer tailored solutions. Internally, it improves productivity by automating repetitive tasks, enabling real-time collaboration, and supporting data-driven decisions (Kraus et al. 2021). However, digital transformation is not without challenges. Organizations face obstacles like resistance to change, skill gaps, cybersecurity concerns, and aligning technology with operational goals (Heavin and Power, 2018). Digital transformation poses strategic, managerial, and governance-related challenges for organizations. It requires strong leadership, agile strategies, and a focus on innovation to develop new digital technologies. Strategically, aligning digital initiatives with operational goals can be difficult, as digital investments may not immediately show returns (Dal Mas et al. 2023). Managerial issues include resistance to change, skill shortages, and the need to upskill employees for technology-driven roles. Governance-related concerns often revolve around data security, privacy compliance, and ethical use of emerging technologies like AI (NHS, 2025). Implementing robust policies to manage digital risks, ensure accountability, and oversee technological integration is crucial in addressing these challenges proactively and essential for successful digital transformation in healthcare (Kraus et al. 2021).

One way to be proactive and successfully implement digital technology is to take advantage of co-design and engage various stakeholders in the design process to ensure that a product is both usable and technically robust (Bird et al. 2021). In healthcare, these stakeholders can include patients, as well as healthcare professionals, technical personnel, and quality managers. The participation of end-users such as patients and healthcare professionals is particularly vital for creating a DHT that provides

good usability, an essential element for fostering engagement and encouraging adoption and compliance (Grindell et al., 2022). Involving users and gathering continuous feedback allows for the early identification of reasons for low engagement. Recognizing issues with engagement or adoption is the first step toward refining the design to enhance user experience (Tay et al., 2021). The DHT can then be improved with interactive and personalized design elements aimed specifically at addressing these concerns and boosting user motivation. Examples of such interactive features include gamification and customized feedback (Grindell et al., 2022). Additionally, examples of user involvement while developing DHT resulted in helping with areas where the system may be overly complex, ensuring it remains straightforward and does not overwhelm users, which can facilitate quicker adoption (Tay et al., 2021). Including patients who represent a diverse age range, tech literacy levels, and physical abilities is crucial for developing an inclusive DHT that is easy to navigate (Henni et al., 2022). Equally important is the need to consider collaboration with healthcare professionals to integrate seamlessly into existing workflows and practices. Furthermore, they must comply with healthcare standards to be effective and reliable for both patients and healthcare professionals (Smith et al., 2023). While co-design is an effective approach to navigating the complexities of developing digital health platforms, it does come with challenges. Issues can arise from insufficient participation and collaboration from patients, particularly over long periods (Osman Andersen et al., 2018; Nyström et al., 2018), as well as from limited time and resources (Osman Andersen et al., 2018), and technical and scaling difficulties (Baxter and Sommerville, 2011).

The design and development of DHT are very complex and can be carried out in many ways. One approach, for example, is a user-centered design (UCD) that aims to design technologies, products, systems, or services that prioritize the needs, preferences, and experiences of the end-users (Abrás et al., 2004). The steps in the UCD process include; (i) understanding users by learning about their pain points, behaviors, and goals, (ii) defining the requirements, identifying key functionalities and features based on user needs, (iii) designing solutions by creating prototypes or mock-ups to visualize potential solutions, (iv) engage users in usability testing to evaluate the effectiveness of the design, and finally (v) integrating and making refinements based on the user feedback

and repeating the process as needed.

It is important to consider the concept of usability to understand the user feedback as well as understand the potential obstacles in engaging with and adopting new technologies. Usability is defined by the ISO-standard as the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO-standard, 2018). In this thesis we explore the digital transformation through DHTs that are impacting the specified users of patients and healthcare professionals. These user groups are represented as two elements of the patient safety model mentioned above. Their specified goals differ, as patients aim to use the DHTs to receive healthcare, while healthcare professionals aim to provide healthcare services. The context under consideration where the DHTs are being used is healthcare setting. Usability deals with three main elements: effectiveness, efficiency, and satisfaction. First, effectiveness deals with the accuracy and completeness with which users achieve their goals. Second, efficiency refers to the resources expended in relation to the accuracy and completeness of goals achieved. Such as less time spent or less effort made to achieve the goal. Third, satisfaction covers users' comfort and positive attitudes towards using the DHTs. Furthermore, the ISO-standard emphasizes that usability is not a property of a product in isolation, but a measure of performance in a specific context with real users (ISO-standard, 2018).

2.4 Digital Nudging in DHTs

As discussed in the previous section there is a need to digitally transform organizations. Co-design and measuring usability is one approach while developing digital health technologies, which aims to make technologies that fit the users' needs. We are faced with the acceptance and decisions of people working in healthcare and people receiving healthcare. As humans, we face choices every day. "Choice architecture" refers to the way choices are presented, and the presentation itself can affect the decisions made by individuals following that presentation of choices (Thaler and Sunstein, 2008). The choice architecture is rarely neutral and most often includes a target for how the preferred choice is (Weinman et al., 2016). Influencing peoples' decision-making process with cues laid out

within the choice architecture has recently been coined as nudging. With the rise of technology that can hold persuasive powers, digital nudging emerged in the literature (Schmitz et al., 2024). For the past few years, the interest in and understanding of digital nudging, specifically within the field of information systems, has been maturing. Digital nudging outlines an approach where people’s cognitive biases are actively used and applied to the design elements embedded within the user interface to affect the digital choice architecture presented to the users (Mirsch et al. 2017; Schneider et al. 2018). The underlying purpose of digital nudges is to serve the users and aid them in making better decisions as judged by themselves. This is described by Thaler as libertarian paternalism, which is arguably what makes nudges ethically acceptable (Thaler and Sunstein, 2008). Nudging in general and digital nudging, in particular, is therefore, intricately linked to upholding the persons’ freedom of choice while guiding them toward a decision that is deemed fruitful for their own long-term goals or societal well-being, in an ethical manner and without removing options (Mettler and Stephanovic, 2023).

Thaler and Sunstein introduced the term nudge as an important element in the choice architecture in 2008 (Thaler and Sunstein, 2008). Thaler received the Nobel Prize for Economics in 2017 for his research on nudges, pointing towards the significance of the work. If we examine the origin and meaning of nudges, nudging theory, which derives from behavioral economics, acknowledges that individuals do not always make informed decisions about their health, welfare, and life in general (Thaler and Sunstein, 2008). Instead, people utilize shortcuts that help simplify the decision-making process. These shortcuts are referred to as heuristics or cognitive biases (Tversky and Kahneman, 1974). Because of the inherent link to cognitive biases, nudging has been illustrated as being heavily reliant on human cognition, which brings us to the notion of bounded rationality and its relation to digital nudging. Bounded rationality encompasses the premise that human cognition consists of two interconnected systems, namely the unreflective, automatic, emotional part of the brain (which is referred to as system 1 thinking) and the reflective, slow, and rational part of the brain (which is known as system 2 thinking) (Kahneman, 2003; Thaler and Sunstein, 2008; Meske and Amojó, 2020).

Nudges are defined as intentional and targeted interventions to

modify the choice architecture and alter an individual's behavior to the desired direction by taking advantage of cognitive biases (Cho and Bates, 2018). One of the most significant examples is when the default option of organ donation was changed from opt-in to opt-out, which nearly doubled the participation in organ donation (Johnson and Goldstein, 2003). Analysis reveals that 62 percent of empirical nudging studies are statistically significant (Hummel and Maedche, 2019). A systematic review and meta-analysis also reveal that nudges result in an average 15 percent increase in healthier dietary or nutritional choices, as measured by a change in frequency of healthy choices or change in overall caloric consumption (Arno and Thomas, 2016). Following the large-scale impact in physical settings, the development of digital nudging has grown as digital choice architecture increasingly influences peoples' lives (Lembcke et al., 2019). Digital nudging has been shown to have a significant impact on decision-making, and the effects in digital settings are comparable to nudging in physical settings (Zhang et al., 2015). The tools of choice architecture can be broken down into several categories (Sunstein, 2014; Bergram et al., 2022). In Table 2.1 below are definitions and examples of how different nudges can be applied in healthcare settings in a digital environment.

Designers can improve digital choices with digital nudging to support individuals in making beneficial decisions and enjoying an enhanced user interface, ultimately increasing user satisfaction (Mirsch, Lehrer, and Jung, 2018). Relying on heuristics and cognitive biases makes digital nudging a powerful tool for designers of digital choice environments because people are subconsciously influenced in their decisions. These persuasive user interface design elements are embedded elements in digital technology and include graphic design, content, wording, and other small features such as user reviews, ratings or push notifications on smartphones that remind the user to be more active (Weinmann et al., 2016). Designers are often not aware of their role in the design of DHTs or if they are aware of it, they lack a systematic approach to designing digital nudges (Mirsch, Lehrer, and Jung, 2018). Therefore, digital choice environments are often designed by trial and error, where best practices are copied from competitors and often modified ineffectively to have an unintended influence on choice architecture, which ultimately impacts the decision-making of the users (Mirsch, Lehrer, and Jung, 2018). This can result in "mind-

Nudge Category	Definition	Example of Nudge as Behavioral or Attitudinal Intervention
Feedback	Provides information about the past or current behavior of a user (Hoffmann and Thommes, 2020).	Notification to a user that he has completed 10,000 steps today or perhaps three days in a row.
Priming	Some underlying psychological mechanisms such as priming (Valdez et al. 2017).	Swiping images on a smartphone screen associated with unhealthy behavior away from the body and images of preferred behavior toward the body.
Social reference	Providing references to how other users behave, thereby creating a social norm. Also, the tendency to want to appeal to the expectations of others (Goldstein et al., 2008).	Receiving information about the progress of other cancer survivors. Being monitored remotely by healthcare professionals or sharing progress with a buddy.
Precommitment	Commitments by users will motivate them to behave in a way that is consistent with the commitments (Schwartz et al., 2014).	Setting goals for healthy eating, regular exercise, or no smoking.
Disclosure	Adding information that is accessible, clear, and relevant to the choice that the user is about to make (Carmichael et al., 2008).	Sharing relevant information about diseases and/or the benefits of getting enough sleep and eating certain types of foods.
Simplification	Behavior can be encouraged or discouraged by removing or adding friction (Hummel et al., 2019).	Making it more difficult for children dealing with problematic smartphone usage to access certain apps. Using sensors to conveniently share information about adherence with healthcare professionals.
Loss aversion	People assign more value to something that is going to be more difficult to acquire in the future (Schmidt and Zank, 2005).	Losing points for unhealthy behavior instead of gaining points for making healthy choices.
Warnings	Different kinds of warnings and graphics assist users by grabbing their attention to various risks and consequences (Hall et al., 2018).	Sharing graphics and information about the danger of smoking or not adhering to treatment.
Default	Design the choice architecture in such a way that the default behavior is the desired behavior (Jachimowicz et al., 2019).	Preselect healthy food options in a grocery app for people who are overweight.

Table 2.1: Common examples of cognitive biases and heuristics that can be exploited to promote behavior or attitudinal change.

lessness” when designing and implementing digital choice architectures (Salovaara et al., 2019). Designing without a clear goal ultimately comes down to a question of responsibility. Responsibility allows us to evaluate transformational digital technologies and the use of digital nudges in a balanced manner, by factoring in both harmful and positive outcomes from the engagement with such artifacts (Voegtlin et al., 2022). A systematic approach to designing digital nudges, considering responsibility and ethics, should be the guiding light for designers when designing user interfaces, choice architecture, and digital services in general. That brings us to the discussion on ethics in design and how it supports designers to positively leverage the transformational powers

of digital technologies.

The importance of ethical consideration in persuasive design is often addressed in the persuasive technology community. Persuasion is generally understood as an ethical approach to behavior change, yet the ethical implications seem to be more recognized by academics rather than generally applied in persuasive technology (Kight and Gram-Hansen, 2019). A common guideline for designers to follow is the “golden rule” principle that “creators of a persuasive technology should never seek to persuade a person or persons of something they themselves would not consent to be persuaded to do” (Berdichevsky and Neuenschwander, 1999). It argues that ethics should be evaluated through the designers’ motivations and methods, as technology merely executes the processes they create and lacks independent intent. Another viewpoint is that computer systems themselves are powerful persuaders because they represent in public opinion a kind of mathematical precision that may serve as a role model of ‘true and accurate’ feedback (Fogg, 2003). Studying moral and ethical principles, along with human rights, can move us beyond subjective individualism and allow us to define ethical principles as the “right and responsible action” (Atkinson, 2006). There have been developed design methods to support responsible persuasive system design. Value Sensitive Design was developed based on “human values” such as “privacy”, “autonomy”, and “moral beliefs of the technology” rather than usability (Davis, 2009). Another method is the Participatory Design which allows the users to be part of the design process and “is very much concerned with social learning and multi-stakeholder negotiation” (Davis, 2009).

Spahn (2011) explores if guidelines for the field of persuasive technology can be grounded in the speech-act aspect. The speech-act theory expands the scope of the philosophical efforts to understand the ‘meaning of words’ beyond the strictly propositional aspects of language (Austin, 1962 and Searle, 1969). There are four implicit validity claims inherent in every speech act (Habermas, 1993). Based on them, Spahn created four guidelines that are relevant for the usage and development of persuasive technology: i) comprehensibility, ii) truth, iii) truthfulness, and iv) appropriateness. *Comprehensibility* is the most basic precondition for communication and refers to the utterance of words to be comprehensible. In the context of digital technology that would translate to the user being able to understand the feedback given

by the digital nudge. Designers of persuasive design should consider if their design is easy to understand. *Truth* can be regarded as the most important validity claim of speech acts from a philosophical perspective. In many cases, digital nudges communicate with the user through various feedback mechanisms. The truth requirement demands that the feedback mechanism gives true information. *Truthfulness* is the property in human communication, to tell the truth in each context, also called ‘honesty’ or ‘truthfulness’ of the speaker. In persuasive system design, it is not always clear who is the ‘author’ of the persuasion. It could be the digital nudge itself, the designer of the digital nudge, or the company or institution that implemented it. It might be enough to interpret ‘truthfulness’ in the case of digital nudges as the reliability and accuracy of a given feedback mechanism. Finally, *appropriateness* concerns the context of the given speech act. For example, a judge can say the word ‘guilty’ and establish a new social fact. But this is true only if spoken under very specific circumstances by a judge in a courtroom, who is entitled to do so. The elements from the speech-act theory can function as guidelines for understanding and designing ethically acceptable digital nudges. It is something that designers can apply, and the guidelines can also support the teaching and learning process.

Chapter 3

Research Approach

In this chapter, I will discuss the overview of the research project, the empirical context, the action design research methodology, the data gathering methodology and analysis, and the studies conducted.

3.1 Overview of the Research Project

This is a paper-based research project that consists of five papers. In this research into patient safety, we rely on a model based on Emanuel et al. 2009 patient safety model and the SEIPS 3.0 model (Carayon et al. 2020) where there are four main elements to patient safety: (i) patients, (ii) healthcare professionals (HCP), (iii) systems of therapeutic action, and (iv) continuous quality improvements (CQI). For simplification, I will refer to ‘systems of therapeutic actions’ as ‘digital health technologies’ as they are the focus of this thesis within ‘systems of therapeutic actions’. See Figure 3.1 for the four main elements. We explore one or more elements in each paper that is included in the thesis.

In the first two papers, we explore two DHTs that are designed and developed for healthcare professionals (elements (ii) and (iii) in Figure 3.1). In paper P1 we introduce a newly developed mobile app to healthcare professionals and based on their feedback we refine the app and develop a final artifact that is further implemented into the work processes of the hospital. In paper P2 we design and develop a digital health program that collects data about the patient’s journey through waiting, undergoing, and re-

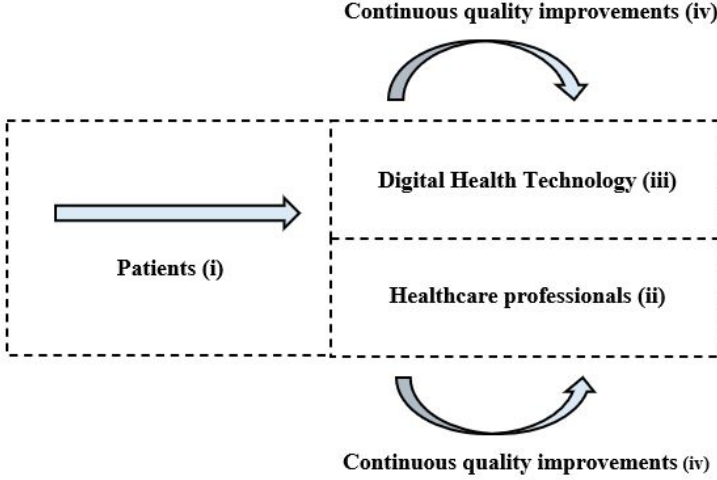


Figure 3.1: Patient safety model based on Emanuel et al. 2009 and Carayon et al. 2020

covering from surgery. Many of the features in the digital health program already existed and were only adjusted to the research of paper P2, while others were developed from scratch. In both papers P1 and P2 we measure the usability of the DHTs and the user experience of the healthcare professionals. In paper P2 we are also exploring the role of DHT in continuous quality improvements (element (iv) in Figure 3.1). In paper P3 we shift the focus away from the healthcare professional and focus on the patient (element (i) in figure 3.1), where we evaluate patient engagement and patient self-reported outcomes using a digital health program. Paper P4 is a systemic review of how digital nudges are applied to healthcare settings influencing the behavior and attitudes of both healthcare professionals and patients (elements (i) and (ii) in Figure 3.1) and examines if digital nudges in healthcare settings are an effective approach. The final paper P5 explores the understanding and attitudes of users toward the usage of digital nudging (elements (i) and (ii) in Figure 3.1). In paper P5 design guidelines were developed for designers and educators to guide ethical usage of digital nudges when designing and developing digital technologies.

3.2 Empirical Context

In 2009, the IT department at National Hospital in Iceland began the process of integrating silo systems to create an integration layer connecting over 70 clinical systems and 9000 medical equipment. This integration layer, also referred to as heavyweight IT (Bygstad, 2017), is the heart of the National Hospital digital health platform and it makes it possible to develop lightweight IT solutions such as apps that support healthcare professionals in their everyday work and research as well as patients in their care journey. The integration layer also opens the opportunity to connect external systems for either healthcare professionals or patients to work seamlessly with hospital systems. That integration layer made it possible to design and develop a web application for healthcare professionals at the National Hospital. The web application is called “Heilsugátt” and gives healthcare professionals access to information in real time, in one place in an ordered manner. The web application hosts many different artifacts and only a fraction of them were subject to the research for this thesis. The artifacts that were studied were electronic whiteboards, registration forms, patient groups, and communication boards. These artifacts are presented by (I) in Figure 3.2 and with more detailed functionality in Table 3.2.

In 2022 development began on a mobile application for employees of the hospital, both clinical and non-clinical. The mobile application for employees is called “Starfsmenn LSH” and allows the transportation services at the hospital to manage tasks. See (II) in Figure 3.2. Healthcare professionals at the hospital can use the app to complete various checklists and upload photos directly from smartphones or tablets to EHRs. The information documented in the mobile application for healthcare professionals is made available on the web application, for example on the electronic whiteboard. In 2020 development began on a mobile application for patients which also relies on the integration layer. The mobile application is called “Landspítalaapp” and shares information about the patient’s treatment, medication, vitals, lab results, appointments, and waiting lists. See (III) in Figure 3.2. The mobile application works seamlessly with the registration forms from the web app as well as the patient groups and the communication boards.

The Sidekick Health digital health program for patients with

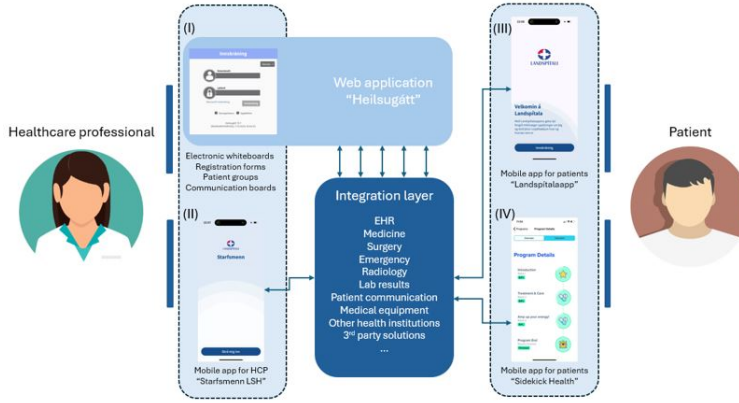


Figure 3.2: Overview of the components of the National Hospital digital health platform

inflammatory bowel disease (IBD) was developed based on evidence-based clinical guidelines with expert medical and behavioral economic principles and gamification (Thorgeirsson and Kawachi, 2013). This 3rd party solution could be an addition to the National Hospital digital health platform. See (IV) in Figure 3.2. The Sidekick Health digital health programs have been developed to support patients in the therapeutic areas of immunology and inflammation, oncology, cardiovascular, and metabolic. The digital health program has been tested with the National Hospital for patients with cancer (Gudmundsson et al. 2022), patients with heart failure (Arnar et al., 2022), and patients with type 2 diabetes (Hilmarsdóttir et al., 2021). The intervention of the IBD program was, however, deployed for use among patients with IBD in Finland and launched for the first time in May 2020.

As displayed in Table 3.1 Study S1 focuses on the design and development of the mobile app for healthcare professionals (II) and its interaction with the electronic whiteboard (I) of the web application. The focus of study S2 is on the registration forms, patient groups, and communication boards of the web app (I) and the interaction with the mobile app for patients (III). Study S3 focuses on patient engagement and health outcomes using an external solution such as Sidekick Health (IV). Study S4 is a systematic review of digital nudging methods that could be applied

	DHT	Artifact	Relevant functionality
(I)	Web application “Heilsugátt”	Electronic whiteboard (Study 1)	Displays a real-time overview of all inpatients for the relevant department. Used on large screens in every inpatient department.
		Registration forms (Study 2)	Used to document various information about patients through the web application, or in the form of questionnaires through the mobile app for healthcare professionals or mobile app for patients. The registration forms can also be utilized to create national registries such as The Icelandic Heart Failure Registry (Ingimarsdóttir, 2024).
		Patient groups (Study 2)	Serve as the patient management system. They are used for waiting lists and as an overview of patients who are being remotely monitored where real-time information is displayed.
		Communication board (Study 2)	An overview and control panel for all communication between healthcare professionals and patients such as educational material, messages, reminders, and questionnaires. Similar to customer relationship management systems (Baashar et al., 2020).
(II)	HCP mobile app “Starfsmenn LSH”	Clinical documentation (Study 1)	Scan the patient’s wristband and complete a security check or photo documentation.
(III)	Patient mobile app “Landspítalaapp”	Digital communication (Study 2)	Answer questionnaires and receive messages, notifications, or educational material.
(IV)	Patient mobile app “Sidekick Health”	Digital health program (Study 3)	Receive educational material in the form of videos and texts. Patients reported energy levels (fatigue), stress, and sleep quality. Earn points for engagement.

Table 3.1: Overview of DHTs and artifacts of the National Hospital digital health platform

to healthcare settings, such as the National Hospital digital health platform, while study 5 explores the ethical considerations when designing with digital nudges.

Information security management is something to consider in terms of developing DHTs including patient data. The National Hospital is subject to the ISO27001 international standard for information security management. Furthermore, incident management and risk assessments are important aspects when it comes to information security. Data from risk assessments and adverse event registrations indicate that there has been success in reducing risks and anomalies in the past year at the National Hospital. The mobile applications developed by the hospital undergo regular security audits by third parties. However, the most important aspect is that employees behave in a responsible manner trying to ensure that only those who have the appropriate rights can use systems/devices with the right data when needed. The

Sidekick Health platform has access to patient data with encryption according to the military-grade 256-bit Advanced Encryption Standard (e.g. General Data Protection Regulations).

3.3 Action Design Research

Some parts of the National Hospital digital health platform were created, developed, and evaluated using a mixed-methods approach within an action design research (ADR) methodology (Sein et al., 2011). ADR is an iterative methodology aimed at discovering practical and innovative solutions to complex issues (Sein et al., 2011). It focuses on addressing real-world problems through an iterative process that engages both researchers and practitioners, while also contributing theoretical insights gained from solving these issues (Sein et al., 2011). As ADR evaluates digital artifacts in their actual usage contexts, it has gained popularity as a research method in information systems (IS) (Cronholm and Göbel, 2019). This approach enables the development of solutions that are both theoretically robust and practically useful (Haj-Bolouri et al., 2017). Additionally, ADR is a participatory method that typically involves a variety of stakeholders in the design and development process, including experts and end-users. This collaboration ensures that the design aligns with the real needs of stakeholders rather than just the needs anticipated by the designers (Sein et al., 2011). Furthermore, action design researchers play an active role in the design and development of solutions to the identified problems.

The applications studied in this thesis are either facing healthcare professionals, such as the web app and mobile app for healthcare professionals, or apps facing patients. The design and development of the National Hospital digital health platform are motivated to meet the needs of healthcare professionals and patients while ensuring patients' safety. The digital health platform serves as the digital infrastructure for the National Hospital, the main hospital in Iceland, as well as serving other health institutions in Iceland such as various primary healthcare providers. The digital health platform constitutes a practical research outcome in the form of digital artifacts that have been developed iteratively and with stakeholder inclusion. The main research question for this thesis is: *How can digital health technologies improve patient*

safety? During the process, the research in this thesis focused not only on understanding the artifacts and improving them but also on contributing to broader discourse on digital health platforms by reflecting on the findings. The ADR project of the National Hospital digital health platform aimed to uncover critical socio-technical aspects and dimensions involved in designing a digital health platform for efficient data collection purposes for healthcare delivery process improvements and to understand the dynamics of addressing emergent challenges in patient safety. This conceptualization can guide the design and development process by focusing on addressing each of the factors appropriately.

The five studies that resulted in five papers included in this thesis form a longitudinal ADR project, where each study marks one or more cycles of the ADR process. The stakeholders involved in these studies include healthcare professionals from different fields, designers, and developers, as well as study participants. Figure 3.3 gives an overview of the entire project and to which stages of the project the five studies in this thesis refer to and labeled in the figure as Study 1-5.

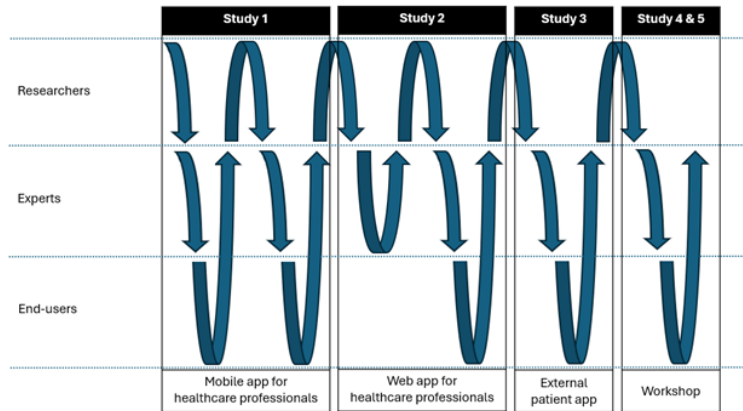


Figure 3.3: The Action Design Research phases of the National Hospital digital health platform and the position of the studies 1-5 within it

The first box in Figure 3.3 represents the research regarding the digital transformation of the mobile app for healthcare professionals (study S1 resulting in paper P1). The second box rep-

resents the design of a digital health journey to collect data for continuous quality improvements through the registration forms of the web app for healthcare professionals (study S2 resulting in paper P2). Then the research on the analysis of user engagement and healthcare outcomes of the external patient app (study S3 resulting in paper P3). Followed by the fourth box represents the research with a focus on digital nudging in healthcare settings (study S4 resulting in P4) and a workshop that leads to design guidelines for ethically designing digital nudges (study S5 resulting in paper P5). The participatory nature of ADR makes it well-suited for the research of digital platforms in a healthcare context. It allows researchers to gain a deeper understanding of the challenges within the healthcare setting from the views of different researchers, experts, and end-users. On the one hand, feedback from healthcare professionals can help uncover pain points in their daily work that could benefit from technological enhancements (Islind, 2022). The iterative nature of ADR allows researchers to design and develop DHT that integrate seamlessly into the existing workflow and match the capabilities of healthcare professionals. On the other hand, close cooperation with the end-user group of patients aligns with a user-centered design that leads to a design with higher user compliance and acceptance (Islind, 2022).

3.4 Data Gathering and Analysis

As mentioned above, the National Hospital digital health platform has been in development for a long time and artifacts are designed, developed, and released every month. Contribution is required by numerous healthcare professionals, digital transformation leaders, developers, and project managers. The research in this thesis focuses on the design and development of sections of the web application and the mobile apps. On the one hand, this includes data from healthcare professionals about the artifacts under examination and, on the other hand, data from patients or participants collected about mobile applications or through a workshop. A few methods were employed to collect both qualitative and quantitative data during the design, development and evaluation of the web and mobile apps. This approach aimed to gain insights into the needs of various stakeholder groups from

multiple perspectives, both in controlled environments and real-world settings.

For qualitative insights, semi-structured interviews, workshops, as well as custom-developed surveys, were utilized. Before the interviews, participants were informed about their purpose, asked for consent to record the sessions, and requested to sign an informed consent form. The data from the interviews was then analyzed using qualitative content analysis (Graneheim and Lundman, 2004). Qualitative content analysis is a method used to analyze qualitative research data. This approach involves collecting, identifying, coding, analyzing, and reporting themes within the data (Graneheim and Lundman, 2004). During the workshops, we wrote down information that was shared by the participants and processed the outcome in the same manner as semi-structured interviews. The custom-developed surveys were designed either to gather demographic information about the participants or to collect their views regarding the usage of different design approaches. The analysis of the open-ended questions from the custom-developed surveys followed the same methodology as the semi-structured interviews. We also used user tasks in study S1 to measure the effectiveness of users achieving their goals.

Quantitative data was gathered using standardized questionnaires and application analytics. The standardized questionnaires included the System Usability Scale (SUS) to measure usability and the AttrakDiff to measure user experience. The SUS, developed by Brooke in 1996, is widely validated. The questionnaire measures usability and is comprised of ten rating scales ranging from 0 to 10, and the ratings are added up to an overall usability score that ranges from 0-100 (Brooke, 1996). The mean SUS score, based on the measuring of multiple artifacts, is 68 and any result below this threshold indicates some underlying issues (Sauro and Lewis, 2016). If the score exceeds 80.3 the system is of high quality. The AttrakDiff measures experienced hedonic and pragmatic quality and user experience of interactive products (Hassenzahl et al., 2003). It evaluates four aspects of the artifact, those being pragmatic qualities (PQ), hedonic qualities – identity (HQ-I), hedonic qualities – stimulation (HQ-S), and attractiveness (ATT). PQ describes the usability and how well the users are achieving the goals. HQ-I indicates how well the users identified with the product. HQ-S measures to what extent a product supports the need to develop and move forward. ATT describes

the global value of the artifact based on the quality of perception. For study S5 we used a questionnaire that was based on a section of the AttrakDiff questionnaire, which only included five scales of the standard twenty-eight scales. We also collected quantitative data through application analytics. We started by eliminating the outliers in the data and then performed descriptive analytics. We measured the usage and engagement of the users and performed statistical tests to see if there were any significant differences between workflows or groups of users. In study S3 we performed predictive analytics to see if the usage during the first week of a digital health program could predict if a patient completed the program. For data analytics purposes we used either Excel, R, or SPSS.

Finally, in study S4 we conducted a systematic literature, where the structure of the review followed the principles of PRISMA (Preferred Reporting Items of Systematic Reviews and Meta-Analysis) (Liberati et. al., 2009). An overview of the data collection is presented in Table 3.2 below. The numbers in the table represent participants in all studies, except for study S4 which is a literature review where the initial search yielded 2995 papers that ended up as 50 papers after the selection process.

Methods	Study 1	Study 2	Study 3	Study 4	Study 5
Semi-structured interviews	21 & 8	7			
Workshop	6	4			
User tasks	21				
Custom-developed survey	21				273 x 3
SUS	21	10			
AttrakDiff	21	10			
Application analytics	10		444		
Literature Review (PRISMA)				50 papers	

Table 3.2: Participants per data gathering method in the included studies 1-5

3.5 Studies Conducted

This thesis analyzes five papers that have been published, accepted with major revision, or are under review in IS conferences and journals. The focus of the thesis contribution thus lies clearly on IS. To interpret the results of the five papers and create a

more general standalone contribution, I followed an approach inspired by the Strawberry analysis for a paper-based Ph.D. thesis (Presthus and Bygstad, 2014). This approach presents four steps for making sense of the results from multiple papers, which entail (i) the creation of a summary for each paper, (ii) the identification of themes and trends, (iii) the abstraction and explanation of these themes and trends, and (iv) the synthesis and framing. I started by creating a summary of each paper, focusing on the key findings and learning presented in each paper. This step paved the way for the identification of themes across the papers. There is a distinction between the first three papers and the last two papers. The first three papers have a clearer connection to designing, developing, and evaluating DHTs that are associated with the National Hospital digital health platform, while the last two papers are more conceptual where we are exploring design approaches and their influence on end-users. The analysis yielded five themes that are mainly covered in each separate paper. However, there is some overlap in the themes between papers and this is represented in the venn-diagram below.



Figure 3.4: Venn diagram showing the themes that also reflect the five studies

The analysis is based on the literature presented in the related

work section and is grounded in the socio-technical system theory. This theory is based on the view that information systems are both technical and social systems, these systems are interrelated and should not be separated when examining an information system (Bostom and Heinen, 1977). The themes that emerged from the synthesis also align with the WHO guiding principles for patient safety 2021 – 2030 (WHO, 2021).

3.5.1 Study 1: Digital Transformation for Bed-side Documentation

Study setting	DHT	Participants	Methods
National Hospital	Mobile app for HCP	35	Mixed Methods

The aim of study S1 is to design, develop, and evaluate a mobile application, "Starfsmenn LSH," for healthcare professionals at the National Hospital. The study aims to enhance patient safety and workflow efficiency by integrating mobile documentation capabilities into the National Hospital digital health platform and the underlying electronic health record (EHR) systems. Specifically, the research focuses on implementing and assessing two key features: (i) Security checks, which involve routine safety checklists to ensure patient safety, and (ii) photo documentation, allowing healthcare professionals to securely capture and store patient images for medical documentation. To evaluate the usability and user experience of the application, the study employs a mixed-method approach, including System Usability Scale (SUS) for usability assessment, AttrakDiff for evaluating user experience, custom surveys on digital health technology usage, user tasks, and semi-structured interviews to gather user feedback, and application analytics to compare usage patterns before and after implementation. The iterative design process, guided by quantitative and qualitative data, was expected to ensure continuous refinement of the application to optimize its effectiveness in enhancing patient safety, real-time documentation, and overall digital transformation in hospital settings.

3.5.2 Study 2: Continuous Quality Improvements for Healthcare Delivery

Study setting	DHT	Participants	Methods
National Hospital	Web app for HCP	10	Mixed Methods

Study S2 aims to design, develop, and evaluate a digital patient journey for individuals with atrial fibrillation (AF) to improve patient safety and support continuous quality improvements. Given the increasing burden of AF patients on healthcare systems, the study aims to explore how remote monitoring and digital health technologies can support proactive patient management, optimize healthcare resources, and enhance patient safety. Key objectives include: (i) Enhancing patient safety by collecting high-quality data at critical stages, such as when ablation requests are submitted, throughout the patient journey, and during post-procedure monitoring. (ii) Improving efficiency in resource allocation by enabling remote monitoring, prioritizing patient visits based on symptom severity, and reducing unnecessary emergency visits. (iii) Empowering patients through a mobile application that provides educational resources, lifestyle guidance, symptom tracking, and treatment reminders, thereby improving health literacy and self-management. (iv) Co-designing the platform with healthcare professionals, clinical experts, and digital developers to ensure it meets the needs of all user groups. (v) Formalizing design principles for digital health solutions that can be applied to broader healthcare settings. Through an Action Design Research approach, the study iterates through alpha and beta versions of the platform, refining it based on usability testing, interviews, and application analytics. The digital transformation of integrating this digital patient journey into AF management, the research seeks to bridge gaps between scientific recommendations, clinical workflows, and patient safety, ultimately improving outcomes and reducing the burden on healthcare providers.

3.5.3 Study 3: Evaluation of Patient Engagement and Patient Outcomes

The aim of study S3 is to evaluate the engagement and initial outcomes of the Sidekick Health digital health program for patients

Study setting	DHT	Participants	Methods
IBD patients in Finland	Patient mobile app “Sidekick Health”	444	Application Analytics

with inflammatory bowel disease (IBD). Specifically, the study aims to: (i) Assess patient engagement with the digital health platform by analyzing user interactions and application analytics. (ii) Investigate the program’s impact on key health factors, including fatigue (energy levels), stress, and sleep quality, which are crucial in managing IBD. The data reported in this preliminary program evaluation were collected using the Sidekick Health platform in a real-world setting. For this evaluation, anonymized data were extracted for further processing and analysis. No personal or identifiable data were included in the data set, which consisted of participants’ demographics and platform interactions. Potential participants were recruited from Finland via local IBD patient association websites and social media (Facebook and Instagram advertisements). Of the 444 adults who registered for the digital health program, 205 (46.2 percent) were included in the intention-to-treat sample. The data collected were baseline characteristics and engagement via participants’ event logs. The patient-reported stress, energy levels, and quality of sleep were assessed using the Likert scale ranging from 0 to 10.

3.5.4 Study 4: Systematic Review of Digital Nudging in Healthcare Settings

Study setting	DHT	Papers	Methods
Systematic review	44 various DHTs	50	PRISMA

After evaluating the Sidekick Health digital health program, which incorporates behavioral economics and cognitive behavioral therapy, study S4 examines the application of digital nudges in healthcare. The aim of study S4 is to explore how digital nudges can be applied in healthcare settings by conducting a systematic review of existing research on digital nudging in DHTs. Specifically, the study examines how behavioral economics and cognitive behavioral therapy approaches influence patient treatment, safety, and management. The systematic review followed PRISMA guidelines and was informed by recent literature. The

search was conducted across Scopus, PubMed, ACM Digital Library, Web of Science, and IEEE Xplore, using broad search terms that included digital nudging, cognitive bias, and behavioral economics. The search included papers that were published until the end of the year 2023, and there was no restriction on the research field to ensure a diverse selection of studies. Inclusion criteria required studies to explore behavior or attitude changes in patients or healthcare professionals, involve disease treatment or prevention, and include empirical experiments conducted in either field or lab settings. The search, completed on March 11, 2024, yielded 2,995 references after duplicate removal. The screening process managed with Zotero, involved reviewing titles, abstracts, and keywords, leading to an initial selection of 136 papers. Full-text analysis further refined this to 48 eligible studies. Two additional recent papers were added, resulting in a final selection of 50 studies.

3.5.5 Study 5: Guidelines for Teaching and Learning about Design

Study setting	Digital Technology	Participants	Methods
Workshop at Reykjavik Uni.	Six screenshots	273	Custom-developed questionnaires

Lastly, the final study 5 ponders ethical considerations regarding persuasive system design (PSD) such as digital nudges. The research approach for this paper is based on a case study. The approach in this case study is interpretive, where we study teenage girls' recognition of PSD, such as digital nudges and dark patterns. The data collected for our case study was of both qualitative and quantitative nature. We collected the data through questionnaires (conducted in 2022) and open-ended questions. The empirical setting consists of fourteen-year-old girls in 9th grade attending an event hosted by Reykjavík University to encourage enrollment in informatics.

For study 5, we conducted a one-step empirical data collection where 273 girls who participated in our data collection were randomly divided into groups. At the beginning of the workshop, the girls were informed that we would be collecting anonymous data for further analysis and research, and informed consent was granted before each data collection. The girls received two short

presentations on PSD followed by a guided discussion. They were asked to complete a questionnaire after each session. The subjects of the presentations were digital nudges, dark patterns, and a discussion on the design elements. We altered the order of the presentations on digital nudges and dark patterns to evaluate if the order had an impact on the results. We split the girls into two groups where 47 percent of the girls ($n=128$) started with a presentation and questionnaire on digital nudging, hereinafter referred to as the digital nudging group. The girls then received a presentation and questionnaire on dark patterns. Followed by a discussion and a questionnaire with qualitative open-ended questions in written format. The other 53 percent ($n=145$) of the girls started with a presentation and questionnaire on dark patterns, hereinafter referred to as the dark pattern group, followed by a presentation and questionnaire on digital nudges. They also completed their participation with a final questionnaire reflecting on the design patterns in open-ended questions in written format. Figure 3.5 shows how we split the girls into groups, how we ordered the presentations and questionnaires, alongside the participation rates in each data collection step. The participation rate diminished with every data collection step presented during the session.

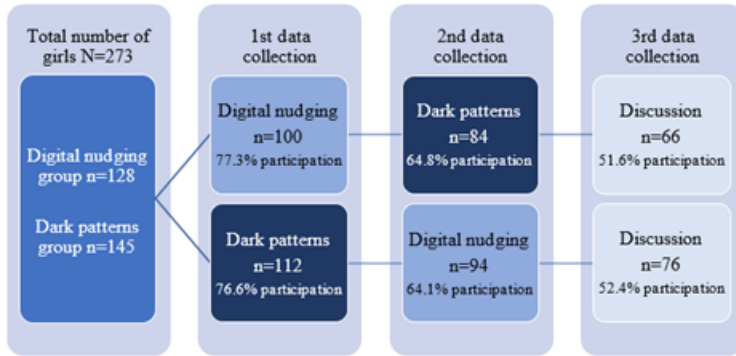


Figure 3.5: Data collection with three custom-develop questionnaires for study 5

3.6 The Researcher Role

One aspect of ADR that sets it apart from other methodologies is the active role the researcher takes (Sein et al., 2011). Instead of researching an artifact from an outsider’s perspective, the action design researcher takes an active role and participates in the design and development of the artifact. At the beginning of my Ph.D. studies, I assumed the role of a researcher of the Sidekick Health mobile app for patients. Later, I transitioned to the role of researcher, designer, and digital transformation leader of the National Hospital in Iceland. I was the main researcher in the research done in collaboration with the digital health platform.

The data from studies S1-S5 were collected over five years. From this data collection, this thesis illustrates results from multiple user evaluations involving a total of 765 participants. I was involved in the process and the conduction of the studies to various degrees. The mobile application for healthcare professionals in study S1 had already been developed for non-clinical employees who were working for the transportation services of the hospital. I joined the process of designing and developing the alpha version of the mobile application then needed serious rewriting of the back-end and front-end. I collected the data for the evaluation of the beta version of the mobile application together with an M.Sc. student in Digital Health Anna Halldóra N. Snorraddóttir who was interning at the National Hospital. The second study S2, which included the analysis of various features of the web application in interaction with the National Hospital mobile app for patients, is a collaboration between doctors and nurses of the Department of Cardiology at the National Hospital. My role in the study was to structure the research approach and collect data for analysis. By the time I started the collaboration with Sidekick Health, study S3, they had already collected the data from patients. My responsibility was to frame the research approach for the program evaluation in collaboration with my co-authors, as well as doing the initial data analysis. Regarding the fourth study S4, the literature review on digital nudging, I performed the material preparation, data collection, and analysis with Steinunn Gróa Sigurðardóttir a fellow Ph.D. student and Associate Professor Anna Sigríður Islind my main supervisor. Finally, I was involved in the planning of the fifth study S5 together with a fellow Ph.D. student Ioana Duta-Visescu. We have already published

one paper from sections of the data set (Visescu et al., 2024). Table 3.6 illustrates my contribution to each paper included in the thesis. The explanation of the abbreviations in the table are as follows: ME = Main effort, includes the main effort in the indicated column. EE = Equal efforts, includes that there was a shared equal effort between at least one other author of the paper (this can for instance be the case when the work behind the paper was divided or when co-authorship has been equally divided between at least two authors). CE = Contributing effort, entails important effort but there is someone else in the author list that delivered the main effort. LE = Learning effort, includes an effort of a learning character, for instance by assisting with the data collection or assisting with the analysis. At least a LE is needed in all columns to fulfil the Vancouver rules for authorship.

Paper name	Idea	Related work & literature	Data gathering	Research Design	Artifact Design	Analysis & synthesis	Draft	Critical review	Administration
Paper 1	ME	ME	EE	ME	ME	ME	ME	ME	ME
Paper 2	ME	ME	ME	ME	EE	ME	ME	ME	ME
Paper 3	EE	CE	ME	EE	LE	EE	LE	LE	LE
Paper 4	ME	ME	ME	ME	ME	ME	ME	ME	ME
Paper 5	ME	ME	EE	ME	EE	ME	ME	ME	ME

Table 3.3: Declaration of authorship contribution

Chapter 4

Results

In this chapter, I will discuss the results of the five papers.

4.1 Making Sense of the Results

As mentioned in section 3.5 above I used the Strawberry analysis as the framework for writing this thesis (Presthus and Bygstad, 2014). This is a step-wise analysis that consists of four steps: (i) creating a summary of the papers, (ii) identifying the themes and trends, (iii) abstraction and explanation of these themes, and (iv) the synthesis and framing. In this chapter, I will cover the first three steps of the analysis. First, for each paper, I will write a summary of the paper highlighting the key findings. Second, the themes that emerged from the Strawberry analysis, which are all factors that can contribute to improved patient' safety, were digital transformation, continuous quality improvements, patient engagement, design for changing behavior, and finally teaching and learning. While summarizing the results of each study I will also draw out the main trends identified from each study. Third, the themes can be applied to the simplified patient safety model based on Emanuel et al., 2009 and Carayon et al., 2020. The model consists of four elements (i) patients, (ii) healthcare professionals (HCP), (iii) digital health technology (DHT), and (iv) continuous quality improvements (CQI). The connection between the studies and the model were also described in section 3.1 of the thesis. Figure 4.1 illustrates how each theme explores some of the elements of the model.

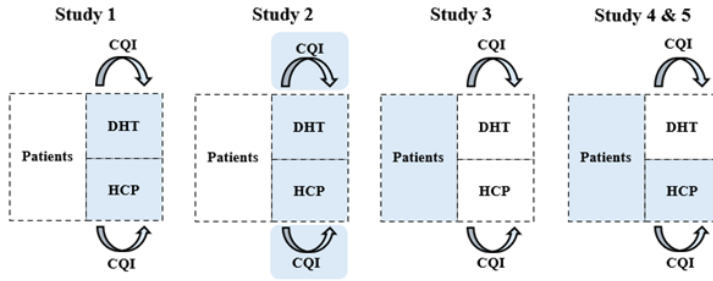


Figure 4.1: How each study relates to a simplified patient safety model

4.2 Paper 1: Digital Transformation of Healthcare Processes

Title: Co-Designing Digital Health Applications: Unravelling the Importance of Mobile Bedside Documentation Practices

Status: Published

Outlet: Americas Conference of Information Systems, 2025

Type of Outlet: Conference proceedings

Full reference: Jóhannsdóttir, L. G., Snorraddóttir, A. H. N., Tracz, A., Óskarsdóttir, M., and Islind, A. S. (2025). Co-Designing Digital Health Applications: Unravelling the Importance of Mobile Bedside Documentation Practices. In *Proceeding of Americas Conference of Information Systems*

Summary of the paper: This paper presents an action design research project aimed at developing a mobile application to enhance clinical documentation for healthcare professionals. The app was co-designed with key stakeholders, including healthcare professionals, department heads, and a digital development team, ensuring it met user needs. The two research questions that we explored were: (i) *What are the benefits and drawbacks of using a desktop computer for clinical documentation in comparison to a digital mobile application?* and (ii) *How can a digital mobile*

application for healthcare professionals be designed and developed to improve patient safety and increase efficiency?

Good clinical documentation practices in healthcare are vital for several reasons. First, accurate documentation helps ensure continuity of care and provides a comprehensive record of a patient's condition, treatments, and responses, which can prevent errors and improve patient safety (McCarthy et al., 2019). Second, proper documentation facilitates clear communication among healthcare team members and ensures that all members of the team are informed about a patient's status and care plan (Asmi-rajanti et al., 2019). Third, detailed documentation allows for the evaluation of the quality of care delivered and helps in identifying gaps in care and areas for improvement, aiding in the development of better practices, protocols, and education (Pine et al., 2023). In hospitals, there remain structural challenges, such as not enough central stationary desktops available for all healthcare professionals to comply with documentation standards, or the equipment might not be best suited for photo documentation. In the fast-paced and unpredictable environment of healthcare professionals there also remain challenges for real-time bedside documentation leading to documentation at the end of the shift that could be subject to memory bias.

Data collection in this study involved surveys, questionnaires, application analytics, user tasks, and semi-structured interviews, with iterative testing phases. The alpha version of the app was first tested in one hospital department, identifying critical issues such as the log-in process and security check procedures not being displayed on the electronic whiteboard. Based on these findings, a beta version was developed and tested in two departments, incorporating user feedback to improve usability. The beta version demonstrated improved efficiency in security checks and photo documentation, with usability tests indicating a generally positive reception. The app significantly reduced the time required for photo uploads and increased compliance with security check documentation. However, some usability challenges remained, such as accidental photo deletions and the need for additional features like improved scanning, better photo quality, and alternative data transmission methods in case of technical failures. Three months after implementation, healthcare professionals reported positive experiences but highlighted the necessity of broader hospital-wide adoption and additional refinement.

The study underscores the importance of engaging healthcare professionals in the design and development of digital health technologies to ensure seamless integration into clinical workflows. It contributes five key design principles for mobile applications in healthcare: a secure and efficient log-in process, the use of scanning technology for documentation, system compatibility, high-quality and secure photo documentation, and comprehensive bedside documentation capabilities. The findings highlight the potential of mobile applications to improve efficiency, enhance patient safety, and support reliable clinical documentation in hospitals.

Five design principles:

- 1. Seamless and secure log-in/out process:** The log-in process needs to be simple and secure so that healthcare professionals do not waste precious time. The log-out process or an automated log-out process ensures that clinical documentation is always done in the right name.
- 2. Utilize scanning technology:** The scanning process improves the usability of the application as well as supports accurate documentation, considering traceability and convenience.
- 3. Compatibility with other solutions:** The mobile application needs to be compatible with other systems in use at the hospital such as the electronic whiteboards and web applications.
- 4. Photo quality and security:** The photo quality needs to have sufficient resolution to capture the details of wounds. There was also great emphasis on the security regarding photos and concerns about how to proceed when it was not possible to send a picture at a certain point in time.
- 5. Comprehensive bedside documentation:** It is important that healthcare professionals can complete most of the tasks that they do during bedside visits. If the app only covers a fraction of the most common procedures, then the value of the application is less in the eyes of healthcare professionals.

This paper belongs to the theme of digital transformation and the main trends identified were that healthcare professionals are

very sensitive to the ease and convenience of clinical documentation, as well as the added value of implementing new DHT. They pointed out the added value of being able to document by the side of the patient, instead of at the central stationary computers, which allowed them to spend more time with the patients rather than in front of the computer screens. However, the inconvenience of documenting only a fraction of the patient's health trajectory in a mobile app and the rest in stationary computers was an inconvenience. I connect the research in this study to the elements of the patient safety model that represent the healthcare professional and the DHT. To answer the research questions, we learned that: (i) a mobile application improves efficiency in security checks and photo documentation, and therefore patient safety, in comparison to stationary computers, and (ii) the process of continuous testing, user feedback, and iterative improvements allows for the design and development of an artifact that fits the needs of healthcare professionals.

4.3 Paper 2: Process Improvements through DHTs

Title: Improved Healthcare Delivery Process for Patients with Atrial Fibrillation: Design Principles and a Novel Digital Health Platform

Status: Under review

Outlet: Health Informatics Journal

Type of Outlet: Journal

Full reference: Jóhannsdóttir, L. G., Erlingsdóttir, Gizurarson, S. Ö., Guðmundsson, K., H. Ý., Kristjánsdóttir, H., Jónsson, B., Óskarsdóttir, M., and Islind, A. S. (under review). Improved Healthcare Delivery Process for Patients with Atrial Fibrillation: Design Principles and a Novel Digital Health Platform. Under review at *Health Informatics Journal*

Summary of the paper: This study also presents an action design research project focused on developing a digital health plat-

form for healthcare professionals managing atrial fibrillation (AF) patients. The platform was co-designed with healthcare professionals, clinical experts, and digital developers to address specific user needs. The research question was: *How can a digital health platform be designed and developed to improve patient safety and increase efficiency for patients with AF?*

Atrial fibrillation (AF) is the most common heart arrhythmia, and if left untreated, it can lead to serious health complications, including heart failure, cardiomyopathy, stroke, dementia, depression, and a diminished quality of life (Virani et al., 2021; Hindricks et al., 2021). In Europe, AF places a significant financial strain on healthcare systems, underscoring the urgent need for strategic planning to meet growing demands (Ringborg et al., 2008). Many of the risks associated with AF can be managed through lifestyle changes (Elliot et al., 2023), making prevention and proactive care essential.

The research involved using a mix of quantitative and qualitative data, including questionnaires, a workshop, and semi-structured interviews. Initially, an alpha version of the patient journey was developed through an expert workshop, identifying key areas for digital transformation, such as digital surgery requests, an AF registry, and remote patient monitoring via a mobile app. See Figure 4.3 for the data collection.

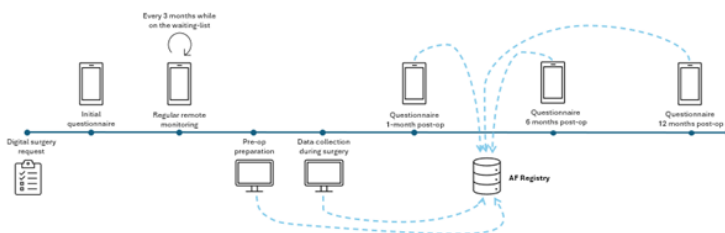


Figure 4.2: Data collection through the AF patient journey

The beta version introduced a structured digital surgery request, registration forms, and a rule-based engine to automate patient communication and monitoring. Testing with ten healthcare professionals revealed usability challenges, as reflected in the System Usability Scale (SUS) and AttrakDiff scores, highlighting areas for improvement. Interviews further identified key concerns,

including patient follow-up, automation in data processing, and equal access to digital healthcare. Based on these findings, the study established five design principles to guide the final artifact. The study concludes that effective data collection is essential for patient safety and healthcare efficiency. Future research should explore integrating smartwatch electrocardiogram tracking, assessing the impact of digital tools on patient knowledge and health literacy, and leveraging the AF registry for comparative studies on ablation procedures and their outcomes.

Five design principles:

- 1. Detailed request for surgery:** It is important for the prioritization of patients into the surgery as soon as possible so that the patients can receive the most appropriate care based on the symptoms.
- 2. Visualization of patient trajectory:** Healthcare professionals have limited time to monitor patients remotely and when a patient is flagged red the nurse wants to have easy access to his recent trajectory and to see the development from past measurements.
- 3. Prioritization of patient waiting list based on real-time data:** From the initial request for surgery and until the patient is called into preparation for surgery many things can change in the health of patients. Educating patients, monitoring their health, and encouraging changed behavior support optimal prioritization.
- 4. Uphold equality and inclusion throughout patient journey:** It is important to consider those who for some reason drop out or cannot participate in a digital patient journey.
- 5. Quick access and visualization of quality indicators:** In order to support decision-making regarding the healthcare process delivery cardiology specialists need to reflect on quality indicators that are easy to access and derive from databases such as the AF Registry.

This paper belongs to the theme of continuous quality improvement and the main trends that were identified were concerns

regarding equity and equality in telehealth, the need for remote monitoring including wearables, opportunities for increasing patient engagement and health literacy, and thereby patient safety. The risk factors that the healthcare professionals were mostly concerned about regarding AF patients were obesity, hypertension, excessive alcohol consumption and smoking, and sleep apnea.

I connect the research from this study to the elements of the patient safety model representing healthcare professionals, digital health technology, and processes of continuous quality improvements (CQI). To answer the research question, we learned that a digital health platform can be designed and developed with a co-design approach with multiple stakeholders. We also learned that for continuous quality improvement purposes, it is necessary to collect data throughout the patient's journey. Going forward we need to study the results from the CQI analysis to reflect how they influence patient safety.

4.4 Paper 3: Patient Engagement to Improve Patient Safety

Title: A new digital health program for patients with inflammatory bowel disease: preliminary program evaluation

Status: Published

Outlet: JMIR Formative Research

Type of Outlet: Journal

Full reference: Oddsson, S. J., Gunnarsdottir, T., Johannsdottir, L. G., Amundadottir, M. L., Frimannsdottir, A., Molander, P., ... and Thorgeirsson, T. (2023). A new digital health program for patients with inflammatory bowel disease: preliminary program evaluation. *JMIR Formative Research*, 7(1), e39331.

Summary of the paper: This study aims to perform a preliminary program evaluation, analyzing engagement and preliminary effectiveness and the effect on participants' energy levels (fatigue), stress, and sleep quality, of a newly developed 16-week digital health program for patients with inflammatory bowel dis-

ease (IBD). The Sidekick Health digital platform is a gamified digital health tool designed to provide evidence-based support and remote patient monitoring for various therapeutic areas. The platform incorporates behavioral economic principles, gamification, and clinical guidelines to encourage lifestyle changes through personalized education, behavior modification goals, and interactive tasks. Specifically, the IBD program aims to enhance patient well-being by reducing stress, increasing energy levels, and improving sleep. Participants engage with the platform by completing weekly modules that include psychoeducational videos, guided mindfulness exercises, physical activity goals, and nutrition tracking. A specialized IBD nurse monitors progress and provides personalized feedback.

A preliminary evaluation of the program in Finland involved 205 participants, with 39 percent completing at least 12 of the 16 weeks. The study found that higher engagement in the first week significantly predicted completion rates, with those actively using the platform early on being more likely to continue. Participants logged an average of 41 interactions per week, with nutrition-related tasks being the most frequently engaged. The evaluation also demonstrated significant reductions in stress levels and increased energy levels among those who completed the program. However, sleep quality improvements were not statistically significant.

Despite promising results, the study had limitations, including potential selection bias toward younger, more motivated users, a lack of medical verification of IBD status, and the absence of a control group. Additionally, attrition rates were relatively high, with engagement dropping over time. Future improvements to the program could focus on refining recruitment strategies, enhancing personalization, and integrating additional monitoring features to better predict and prevent IBD flare-ups. Overall, the findings suggest that digital health interventions like Sidekick Health can be valuable supplements to traditional IBD care, particularly in improving patient-reported stress and energy levels.

This paper belongs to the theme of patient engagement and the main trends identified were that it is important to get patients engaged at the beginning of a program. It also seemed useful to apply approaches such as feedback and reminders to encourage patients to alter their behavior towards a healthier lifestyle. The research from this study can be connected to the element of the

simple patient safety model that represents patients. We are exploring how patients behave after they sign up for a digital health program and how they interact with the DHT. Even though the specialized IBD nurse was monitoring the progress of the patients, the program was mainly running on its own.

4.5 Paper 4: Applications for Digital Nudges in Healthcare Settings

Title: Digital Nudging in Digital Health Technologies: A Systematic Review

Status: Accepted with minor revisions

Outlet: Health and Technology

Type of Outlet: Journal

Full reference: Jóhannsdóttir, L. G., Sigurðardóttir, S. G., Óskarsdóttir, M., and Islind, A. S. (forthcoming). Digital Nudging in Digital Health Technologies: A Systematic Review. Accepted with minor revision for *Health and Technology*

Summary of the paper: The study systematically reviews the application and effectiveness of digital nudging in digital health technologies (DHTs) by analyzing 50 papers covering 76 experimental studies and 96 nudging scenarios. We synthesize research on how digital nudging utilized to enhance DHTs by addressing the research question: “*How can digital nudges be used within digital health technologies in healthcare settings to support patient treatment, safety, and management?*” Most digital nudging interventions were delivered through mobile applications, either alone (62 percent) or in combination with devices such as smartwatches (18 percent), which were used to measure physical activity, heart rate, or behaviors like smoking. Other interventions included SMS messages, VR glasses, robots, and web applications. The study categorized nudging techniques into feedback, priming, social reference, precommitment, disclosure, simplification, loss aversion, warnings, default, and framing. With feedback nudges being the most used. Most studies (80 percent) were conducted in real-

world settings involving patients with various medical conditions, including obesity, diabetes, heart disease, and mental illness. The interventions lasted from single sessions to 18 months, with an average duration of three and a half months.

The study identifies six healthcare themes where digital nudges were applied: metabolic and physical activity, treatment adherence, addiction diseases (excessive drinking and smoking), rehabilitation, mental health, and children's health. Almost half of the studies explicitly referenced digital nudging, while others used related concepts such as behavioral economics and gamification. The outcomes of digital nudging interventions were analyzed in terms of behavior and attitude changes, with studies split between these two outcomes. Of the 50 papers, 29 reported statistically significant or insignificant effects, with 24 showing significant positive results.

For metabolic and physical activity, feedback nudges and social reference strategies led to increased exercise, healthier diets, and weight loss, although excessive reminders sometimes reduced motivation. In treatment adherence, nudging techniques such as simplification, disclosure, and precommitment improved medication adherence for conditions like asthma, diabetes, and heart disease. Considering addiction disease, cognitive bias modification techniques such as approach-avoidance training helped reduce alcohol consumption and smoking, with interventions using VR and gamification showing promise. Rehabilitation studies showed that social reference and digital group therapy supported recovery, particularly for breast cancer survivors and patients recovering from heart surgery. Mental health interventions, including biofeedback devices and robotic companions, had mixed results, with some nudges improving psychological well-being, while others showed no significant effect. Digital nudging for children yielded inconsistent results, with only two studies showing significant behavioral improvements, suggesting the need for more targeted interventions.

The study highlights that digital nudges can effectively support behavior change in healthcare, particularly in promoting lifestyle changes (diet, physical activity, smoking cessation, and reducing alcohol consumption) and improving treatment adherence and symptom tracking (for both physical and mental disorders). The combination of nudging techniques within DHTs makes it difficult to isolate the effects of individual nudges. The

study underscores the importance of digital nudging in healthcare management, particularly in promoting self-care and remote monitoring, which can help address large-scale healthcare challenges. The review also points to opportunities for integrating social support mechanisms in rehabilitation and taking into account ethical considerations, especially in interventions involving children.

This paper belongs to the theme of designing for changes in behavior and the main trends include lifestyle change, treatment and symptom tracking, rehabilitation, and children's health. The main nudging methods used were feedback, priming, social reference, and precommitment. I connect the research from this paper to the elements in the patient safety model representing the patients and healthcare professionals, even though only a few studies in the review examined healthcare professionals. For patients digital nudges can improve patients' safety by encouraging a healthier lifestyle, improving treatment adherence and symptom tracking. For healthcare professionals digital nudging can help them adhere to guidelines and also give them access to more information if the DHT encourages documentation.

4.6 Paper 5: Design Guidelines for Education and Training

Title: Two Sides of Persuasive System Design: Understanding Digital Nudging and Dark Patterns and its Impact on Teenage Girls

Status: Accepted for publication

Outlet: Behaviour and Information Technology

Type of Outlet: Journal

Full reference: Jóhannsdóttir, L. G., Visesco, I., Lárusdóttir, M. K., Óskarsdóttir, M., and Islind, A. S. (2025). Two Sides of Persuasive System Design: Understanding Digital Nudging and Dark Patterns and its Impact on Teenage Girls. *Behaviour and Information Technology*

Summary of the paper: The study employed a case study approach to examine how teenage girls recognize persuasive system design (PSD) elements, including digital nudges and dark patterns. The research combined qualitative and quantitative data collection methods, using questionnaires and open-ended questions. The study was conducted in 2022 at a Reykjavík University event aimed at encouraging girls to pursue informatics. Participants consisted of 273 fourteen-year-old girls in the 9th grade, who were randomly assigned into two groups. One group was first introduced to digital nudges, while the other started with dark patterns, allowing researchers to assess whether presentation order influenced recognition. We formulated the following research question: *How well do teenage girls recognize PSD after receiving a lecture on persuasive design methods?*

The data collection process followed a structured approach, beginning with interactive presentations on digital nudges and dark patterns. These presentations incorporated real-life examples, visual aids, and guided discussions. After each lecture, the participants completed a questionnaire, which included screenshots of digital interfaces to assess their ability to identify instances of digital nudging or dark patterns. The final phase of the session involved a guided discussion, where the girls shared their thoughts on trust and manipulation in online decision-making. The analysis revealed that, overall, participants found it challenging to recognize PSD, although they performed slightly better at identifying dark patterns (48.8 percent) than digital nudges (41.0 percent). Notably, those first exposed to dark patterns demonstrated a higher accuracy in identifying PSD in subsequent exercises. The guided discussion further highlighted a stronger response to dark patterns, with 68 percent of participants citing examples of deceptive online practices, such as hidden costs and automatic subscriptions. In contrast, only 32 percent mentioned instances of digital nudging, such as prompts in language-learning or grocery-shopping apps.

The study also examined the participants' attitudes toward PSD. While 16 percent expressed positive views, recognizing the potential benefits of digital nudges, 31 percent conveyed negative sentiments, describing these design strategies as unfair or manipulative. Responses indicated that the participants distinguished between ethical and unethical applications of PSD, with many believing that digital nudges were acceptable while dark

patterns were not. Some responses demonstrated a nuanced understanding, acknowledging that companies use these techniques for business purposes while expressing a preference for ethical design practices. The findings contribute to discussions on ethical PSD implementation and provide insights for educators and designers in promoting awareness of digital persuasion techniques.

This paper explores the ethical implications of persuasive system design (PSD), particularly digital nudging and dark patterns, within the framework of bounded relationality. It highlights how these design techniques predominantly engage System 1 thinking—automatic and emotional reasoning—raising ethical concerns about user autonomy and informed decision-making. The study focuses on teenage girls' recognition and perception of PSD elements, offering insights into their comprehension of digital nudging and dark patterns.

Educational strategies are recommended to enhance digital literacy and critical thinking among teenagers, fostering awareness of both ethical and unethical design practices. The research underscores the role of designers in ensuring responsible digital experiences while advocating for participatory design approaches that incorporate user voices, particularly from marginalized groups, to create more ethical and inclusive digital environments. The contribution of this paper can be summarized in a set of design guidelines for ethically persuasive system design which can be used by designers and educators. The design guidelines are three in total: (i) transparency, (ii) responsibility, and (iii) inclusion. We present each of those in more detail here below.

Transparency should be the main priority for designers and educators when designing or teaching about user interfaces. For designers, this means making the design easily understood for teenage girls, always based on true content, while keeping in mind the needs and vulnerability of teenage girls. For educators, this means sharing the knowledge and awareness of the truthfulness and appropriateness of PSD.

Responsibility should be considered a defining feature of PSD when designing for vulnerable groups such as teenagers or children. Our case study shows that teenage girls were more accepting of dark patterns if they were first exposed to the benefits of digital nudges.

Inclusion refers to engaging users, including underrepresented groups like teenagers, directly in the design process. Gather their feedback and insights to ensure that design decisions meet user needs, while also preventing the creation of harmful usage patterns that could exploit vulnerabilities.

This research explores the theme teaching and learning, focusing on how digital nudging can be a powerful design strategy while raising ethical concerns, especially when designing for children. We tested three digital nudging scenarios with teenage girls. Two were based on well-being and fitness apps, using either loss aversion or social norms to influence behavior. The third scenario featured a default setting designed to promote environmentally friendly choices. Despite receiving a lesson on digital nudging, the girls struggled to recognize the technique in action.

I connect this study to the simple patient safety model, particularly its representation of patients and healthcare professionals. In study S4, we found that children did not respond strongly to digital nudges in healthcare settings. This suggests that involving children or teenagers in a co-design process could be valuable, helping them better understand and engage with these methods. However, study S5 highlights the challenges of effectively involving children as a user group. While this study focuses on teenagers, some findings might also apply to younger healthcare professionals, such as nurse associates, who tend to be part of a younger demographic.

At its core, this study is about teaching and learning, ensuring end-users are aware of the approaches in the design. But for that to happen, they first need to understand the methods being used. The high dropout rate during our sessions suggests that not all participants were open to learning something new. This raises an important question: How can we create more engaging, accessible ways to teach digital nudging, particularly when working with younger audiences?

Chapter 5

Synthesis

To ensure patient safety through digital health technologies they should aim to lower risks, reduce the occurrence of avoidable harm, make errors less likely, and reduce the impact of harm when it does occur. This thesis offers a perspective on the design and development of digital health platforms with the aim of improving patient safety by combining insights from five research papers with the overarching narrative about patient safety. Together, they uncover the complexities of designing and developing digital health platforms while highlighting their crucial impact on both healthcare professionals and patients in clinical settings. This research takes you through the journey of DHT development, from its earliest design concepts and initial testing to the implementation in real-world healthcare environments, with patient safety at the heart of every step. In my role as a digital transformation leader and digital product manager at the National Hospital, I played a central part in shaping, researching, adopting, and scaling these technologies. Thanks to this hands-on involvement throughout DHT's lifecycle, my research provides a unique window into the challenges and triumphs of building sections to an existing digital health platform from the vantage point of a product manager. This perspective allows me to draw conclusions about the essential aspects of digital health platforms, grounded in practical, real-world experience and addressing the growing demand for more practice-oriented research in the field of information systems. In this chapter, I will address the final step of the Strawberry analysis which is the synthesis and framing

of the results of the five papers. First, I will draw on the themes that were identified and synthesize the results from the research based on them. Second, I will present more specific dimensions for DHTs that support patient safety based on the key findings of the five studies.

5.1 The Themes for Patient Safety

There are a few ways in which the studies included in this thesis could be categorized into themes. The first two studies are based on user-centered design approaches. The first three studies all have in common that we are studying DHTs firsthand and their influence on patients or healthcare professionals. The first four studies explore DHTs through some perspective of patient safety. The last two studies examine digital nudges as a method for designing, and the final study examines teenagers' attitudes and understanding of persuasive system design such as digital nudges. The themes that I settled on were the following: (i) digital transformation, (ii) continuous quality improvements, (iii) patient engagement, (iv) design for changing behavior, and (v) teaching and learning.

Digital Transformation through DHT:

Integrating DHT into healthcare organizations, fundamentally changing how healthcare professionals operate and adapt to an increasingly digital world is called digital transformation (Kraus et al. 2021). This process goes beyond simply adopting new tools; it involves reshaping mindsets, workflows, and processes to leverage technology effectively (Kraus, 2021). Digital transformation in healthcare seeks to improve patient safety, and usability, drive innovation, and enhance patient and healthcare professionals' experiences and engagement (Lane, 2011). Lessons learned about digital transformation from the research of our studies are that if DHTs are well designed they can increase efficiency and enhance the workflow of healthcare professionals (study S1 and S2). If they bring healthcare professionals added value to their work, and are not adding to the workload, they are more likely to be adapted into the work processes. The added value is reflected in effectiveness and efficiency, which are two elements within usability. One of the most appreciated benefits is the ability to

document patient care directly at the bedside rather than being tied to stationary computers. This shift allows healthcare professionals to spend more time engaging with patients instead of staring at screens. However, challenges remain, having to split documentation between mobile apps and traditional desktop systems creates inefficiencies and frustration. We also learned that beyond documentation, DHT can unlock new possibilities for telehealth and remote care (study 2-4). For instance, we saw from the systematic literature review that smartphones and wearable can provide seamless data transmission, reducing manual input while improving real-time monitoring. An example is how patients' daily step counts were automatically synced to the digital health platform, demonstrating the ease of passive data collection. Another example is how DHTs enable patients to recover from the comfort of their own homes while still being closely monitored by healthcare providers. These advancements illustrate how digital transformation is not just about efficiency but also about creating more patient-centered and flexible care solutions that support patient safety.

Continuous Quality Improvements (CQI) through DHTs:

There are many ways to conduct CQI in healthcare and what they have in common is that they all rely on systematic approaches to enhance patient safety, quality of care, and operational efficiency (McLaughlin and Kaluzny, 2006). The National Hospital relies on root cause analysis (RCA) which is a problem-solving method that investigates underlying causes of adverse events to prevent future occurrences. Every adverse event is carefully examined and assessed where managers identify the root cause, determine corrective actions, and communicate with healthcare professionals, patients, and their families as needed, in collaboration with the quality manager. In 2024 there were 5663 adverse events reported at the National Hospital and only 4 percent of those were categorized as being related to technology including both equipment and computer software. Other methods are less reliant on the reporting of adverse events. They include benchmarking, which relies on comparing performance metrics, or so-called Plan-Do-Study-Act (PDSA) Cycles that use iterative methods where changes are planned, tested on a small scale, evaluated, and adjusted before full implementation (NHS, 2021). For both benchmarking and PDSA collecting data throughout the patients' journey is vital to

create quality indicators and that is where DHTs can make a difference. In study S1 we created simple quality indicators of clinical documentation practices, and we showed that the introduction of a mobile app increased efficiency in security checks and photo documentation. In study S2 we designed a digital patient journey to collect data about patients waiting for, undergoing, and recovering from AF ablation surgery. What we learned from the design process is that healthcare professionals need to be able to visualize the data in an accessible way in order to study and act on the insights gained. Also, when analyzing adverse events, it should be done in the context of the patient's journey rather than a single episode, highlighting the importance of collecting data throughout the patient's journey. Finally, from study S3 where we created indicators representing the self-reported patient outcomes regarding stress, fatigue, and sleep, we saw that patients who engaged with the digital health program showed improvements in terms of lowering stress and fatigue. DHTs can generate vast amounts of data that can drive patient safety and allow for a more sophisticated analysis of the delivery process of healthcare services, setting the groundwork for continuous quality improvements like patient safety and improved patient outcomes (McDonald et al., 2024; Singh and Sittig, 2016). However, we also learned through the research in study S2 that healthcare professionals have very limited time to participate in CQIs and that dedicated healthcare professionals sometimes devote their personal time, often without compensation, to engage in those activities.

The role of Patient Engagement in Patient Safety:

Patient engagement refers to the active participation of patients in their own healthcare to improve outcomes and experiences (Pomey et al., 2015). It involves collaboration between patients, healthcare professionals, and DHTs, ensuring individuals have the knowledge, skills, and confidence to make informed decisions (Irizarry et al., 2015). Engaged patients are more likely to follow treatment plans, adopt healthy behaviors, and manage chronic conditions effectively (Sawesi et al., 2016). Patient engagement is a patient-centered approach that emphasizes communication, trust, and empowerment (Karni et al., 2020). What we learned from examining patients' engagement with a digital health program in study S3 is that the first week of the program can significantly predict the likelihood of completing the whole program. We

also saw where patients engaged with the health program there were significant improvements in self-reported health outcomes, indicating thereby improvements in patient safety for patients with IBD. During the design process of study S2 we learned that patients with AF have inadequate knowledge about their condition (Erlingsdóttir et al., 2023) and that healthcare professionals see an opportunity to improve patient health literacy with the use of DHTs.

Digital Nudging as a Design Method to alter Behavior:

As mentioned in the theoretical background of this thesis “choice architecture” refers to the way choices are presented, and the presentation itself can affect the decisions made by individuals following that presentation of choices (Thaler and Sunstein, 2008). Nudging is when people’s decision-making process is influenced by cues laid out within the choice architecture. The purpose of digital nudges is to serve the users and aid them in making better decisions *as judged by themselves*, which is arguably what makes nudges ethically acceptable (Thaler and Sunstein, 2008). In study S4 we explored how digital nudges are applied in healthcare settings, and how they impact healthcare professionals’ and patients’ attitudes and behavior. Digital nudges can be applied to DHTs to influence the choices of healthcare professionals to follow clinical guidelines that thereby improve patient safety. From study S4 we also learned that digital nudges could have a significant impact on changes in the behavior and attitude of patients regarding healthier lifestyle choices, as well as treatment adherence and symptom tracking for patients with chronic diseases, which ultimately support the improvements of patient safety. Furthermore, the most common methods for digitally nudging patients were through feedback, priming, social reference, and precommitment. We saw in study S3, that digital nudges embedded in the digital health program, that patients reported better outcomes in terms of stress and fatigue. In study S2, the healthcare professionals expressed concerns about how to effectively encourage healthier lifestyles and digital nudging is something to consider for that group of patients.

Teaching and Learning about DHTs:

This theme covers a broad spectrum, but in relation to patient safety, it focuses on two key aspects. First, it involves teaching

healthcare professionals different design approaches, helping them recognize, understand, and potentially apply specific technologies to improve care. Second, it highlights the patient perspective, ensuring they not only understand these design approaches but can also assess when they serve their best interests. Patients should be able to distinguish the intent behind a particular design, recognizing both the benefits and the motivations of those who developed or implemented the DHT they interact with in their healthcare journey. Teaching healthcare professionals to effectively use new DHTs has been a persistent challenge throughout this research. At the National Hospital, there is little structured onboarding for new employees and recent graduates in terms of digital literacy. Instead, they typically learn from colleagues already working in the department, which often results in outdated habits being passed down over time. This lack of standardization leads to significant variations in training across departments.

5.2 Dimensions in Design that May Ensure Patient Safety

In addition to synthesizing the main trends into the themes above, I have framed the key findings, design principles, and ethical guidelines into six dimensions that have the potential to support patient safety design in DHTs. Learning from this study provides insights into the generally desirable dimensions of information systems concerning safety. Each dimension: accessible, engaging, inclusive, responsible, transparent, and valuable, combines insights derived from our findings.

Accessible: There are at least three things to consider regarding accessibility based on this study. First, seamless and secure access to the DHTs. In the fast-paced environment of clinical settings, it is vital to have easy access to DHTs without compromising any data security measures. That means simple and secure login/logout features. Second, access to the relevant information within the DHTs in use and compatibility with other systems in use at the hospital such as electronic whiteboards and web applications. Third, healthcare professionals prefer to be able to access all the artifacts they need to perform their daily tasks in

a single DHT. The second and third points can be summarized in the importance of integrating solutions into the existing digital health platform.

Engaging: An engaging platform encourages consistent use leveraging design elements that promote active participation. From this study, we saw that patients who engage with digital health programs show more positive health outcomes. We also learned that using digital nudging methods as interventions can improve lifestyle choices, adherence to treatment, and symptom tracking. Furthermore, we need to consider the right timing and content when engaging with patients and healthcare professionals. For example, delivering timely and meaningful insights, and alerting healthcare professionals to prioritize safety concerns without overwhelming them. The most common digital nudges applied in healthcare settings through DHTs were feedback, priming, social reference, and precommitment.

Inclusive: Digital health platforms designed to support patient safety can be considered inclusive, accommodating the diverse needs of healthcare professionals and patients. First, we refer to the inclusion of end-users of the DHT such as patients and healthcare professionals. This involves considering differences in language, age, and technological proficiency. Inclusive design ensures that features are universally intuitive and functional, allowing everyone, regardless of ability or expertise, to safely engage with the DHT. It is important to uphold equality and inclusion throughout the patient journey, considering those who for some reason drop out of a digital health program or cannot participate in a digital patient journey. DHTs such as mobile applications for remote care also give patients access to their health data irrelevant of geographic location. The goal is to foster inclusivity, and equitable participation, ensuring that no group is marginalized. Second, inclusion refers to engaging users, including underrepresented, directly in the design process. Gather their feedback and insights to ensure that design decisions meet user needs, while also preventing the creation of harmful usage patterns that could exploit vulnerabilities.

Responsible: Based on our study we can consider responsibility in two ways. First, it is a matter of using the DHTs responsibly to

collect the relevant data to prioritize patients as soon as possible so that they can receive the most appropriate care based on their symptoms. It is also important to responsibly collect relevant data that can be utilized in performance metrics and quality indicators. Furthermore, data can also be shared or collected with the means of educating patients, monitoring their health, and encouraging changed behaviors to support optimal prioritization. Second, with the knowledge of different design approaches designers should avoid “mindlessness” when designing and implementing digital choice architectures. Designers should take advantage of design approaches such as digital nudges when there is an opportunity to nudge patients and healthcare professionals toward the optimal choice that aligns with the judgment of the user. When designing and developing DHTs designers should take advantage of that without limiting the choices of end-users and respecting their autonomy. They should be particularly careful when designing DHTs intended for vulnerable users such as children and teenagers. These two points can be summarized in the notion that designers and developers need to foster a moral compass. Responsibility in digital health platform design prioritizes ethical considerations and safeguards to protect users. Developers must align their goals with patient safety and health outcomes, ensuring the platform amplifies responsible clinical decision-making.

Transparent: In terms of transparency, I have summarized the key findings in three aspects. First, both patients and healthcare professionals benefit from some insight into how the platform processes data, provides recommendations, and flags safety risks. It is important in general when designing information systems, and in particular when designing DHTs to inform the end-user when something goes wrong. Error messages and alternative routes are vital when dealing with sensitive and critical data such as health data. Clearly explaining decision-making logic, and any limitations can enhance credibility and ensure informed engagement. For example, a clinical decision support system should indicate the evidence behind its alerts, enabling healthcare professionals to evaluate and trust its guidance. Second, visualization of data is important for transparency. Healthcare professionals have limited time to monitor patients remotely and when a patient is flagged red the nurse wants to have easy access to their recent trajectory and to see the development from past measurements. Further-

more, to support decision-making regarding the healthcare process delivery, healthcare professionals need to reflect on quality indicators that are easy to access and derive from clinical registries. Third, transparency should be the main priority for designers and educators when designing or teaching user interfaces. For designers, this means making the design easily understood always based on true content, while keeping in mind the needs and vulnerability of the users. For educators, this means sharing knowledge and awareness of the capabilities of the design approaches. Transparency is also about educating the end-users about the design approach at play, whether it is some kind of persuasive system design such as digital nudging, standardized procedures, or any other decision-support.

Valuable: DHT needs to bring value and personal gain for the end-users to change their behavior or attitude. This is relevant for healthcare professionals in terms of making their work more efficient and accurate, such as with scanning technology or being able to complete all bedside measurements while with the patient and seeing that reflected in the web application. Healthcare professionals also need to see the value in their documentation and how that reflects the service provided. This is relevant for patients as DHTs must deliver tangible value by addressing real patient safety challenges, improving quality of care, and meeting user needs effectively. Ongoing user feedback and outcome evaluations are crucial to ensuring the DHTs remain relevant and adaptive, continuously providing value to healthcare professionals while advancing patient safety objectives. Here the concept of usability is very relevant as it comprises of the three elements effectiveness, efficiency, and satisfaction that all contribute to measuring how the users value and experience the DHT.

Chapter 6

Discussion

Digital health technology plays a large role in healthcare in general, and for patient safety and the work of healthcare professionals in particular (Mathews et al., 2019). The system for healthcare delivery is continuously becoming more digital and the clinical environment for both patients and healthcare professionals is in some cases shifting away from traditional settings to be provided, documented, and evaluated through DHTs. This shift brings along opportunities to improve patient safety through the design and development of new and intuitive DHTs. However, it does not come without its challenges. In this thesis, we have explored the co-design process of two DHTs that are part of the National Hospital digital health platform. Namely the mobile application for healthcare professionals (paper P1) and the digital health program for patients with atrial fibrillation (paper P2). Going through the co-design process with healthcare professionals, experts, and developers has yielded design guidelines that have been generalized into dimensions. The mobile application has the ability to ensure patient safety through the support of better clinical documentation as well as the design that sends photos directly to the patient's EHRs. The atrial fibrillation digital health program was an example of how data collection using registration forms can allow for continuous quality improvements in healthcare delivery. The preliminary program evaluation of the Sidekick Health digital health program for patients with IBD represented an example of a 3rd party digital health technology (paper P3). The Sidekick Health DHTs have been integrated with

the National Hospital digital health platform allowing healthcare professionals to access the Sidekick Health portal to view the patient's development. The research showed that patients who are engaged with the health program report better health outcomes and those who are active at the outset are more likely to complete the program. This led us to explore how behavior changes through design such as digital nudges that can influence patients and healthcare professionals in clinical settings (paper P4). Closing this overall action design research project with a workshop to investigate end-users understanding and attitude towards persuasive system designs such as digital nudges (paper P5). In this chapter, I will reflect back to the main research question of the thesis and summarize the practical contributions and theoretical contributions regarding patient safety through DHTs.

6.1 RQ: How can DHT improve patient safety?

Building a DHT is as much about understanding people and processes as it is about leveraging technology. One of the most significant learnings from this journey is that success depends on creating value for both healthcare professionals and patients. A digital health platform can serve as a bridge that connects diverse stakeholders, simplifies complex workflows, and enhances the delivery of care and patient safety. Success lies in understanding user needs and designing a platform that integrates seamlessly into the realities of clinical practice. One critical insight from this work is the importance of involving various stakeholders. Building a successful digital health platform requires involving healthcare professionals, patients, and experts, early and often in the design process. The platform is more likely to address real-world challenges and achieve higher adoption rates when co-designed with those who will use it. This collaborative effort must also extend across disciplines, requiring close partnerships between technical developers, healthcare professionals, and organizational leaders. An iterative development process emerges as another cornerstone of success. Rarely is the first version of a digital health platform perfect or even complete. Through continuous testing, user feedback, and iterative improvements, the platform matures over time, addressing gaps and adapting to evolving needs. Failure should

be embraced as part of the process; each misstep offers valuable lessons that shape the platform's development. The platform must be designed not just for the immediate needs of its users but with an eye to future growth and broader applications. Building with modularity and interoperability ensures it can evolve alongside advancements in technology and shifts in healthcare priorities. Ultimately, the greatest learning is that a successful digital health platform is not built with technology alone, it is built with empathy, collaboration, and a commitment to improving patient safety.

This thesis examines certain aspects of the design and development of digital health technologies and how they can contribute to improvements in patient safety. In organizations with complex work practices, such as hospitals, it is generally recognized that only the users themselves know the practice sufficiently well to be able to assess the suitability of the system (Malm-Nicolaisen et al. 2024). Inclusion in design can take many forms. One approach, for example, is a user-centered design (UCD) that aims to design technologies, products, systems, or services that prioritize the needs, preferences, and experiences of the end-users (Abrams et al., 2004). Our approach in the first two studies is loosely based on the methodology of UCD as we actively involved healthcare professionals throughout the design and development process to ensure that we were designing a final artifact that is intuitive, accessible, and effective. We started the process of development by trying to understand the pain points, goals, and behavior of the healthcare professionals, and together with them we defined the requirements, key functionalities, and features based on their needs. Then we designed alpha versions of the solutions which were either mockups to visualize the potential solution or prototypes of the DHT. At that stage we would test the DHT with either healthcare experts who co-designed the solution or with the healthcare professionals, engaging users in usability testing to evaluate the effectiveness of the design. The final step in the design process was to integrate and refine the DHT, making improvements based on healthcare professionals' feedback and repeating the process as needed.

In this thesis, we set out to answer the research question: *How can digital health technologies improve patient safety?* Through research described in the five papers and included in this thesis and the writing of the cover text I have learned that DHTs that

have the ability to ensure patients' safety require co-design, user-centered design, iterative, and interdisciplinary approach that prioritizes both healthcare needs and system usability. The approach begins with an understanding of the safety challenges within healthcare environments. Working closely with healthcare professionals and patients in a co-design process can ensure the technology addresses real-world problems while aligning with the practical constraints of clinical settings. Technologies must be intuitive, minimize cognitive workload, and seamlessly fit into existing workflows to prevent new errors from emerging. Digital health technologies need to integrate with existing infrastructure and other healthcare systems to provide a complete and accurate view of patient data. This reduces redundancy and ensures better coordination across care teams, which is vital for patient safety. Finally, continuous education and training for healthcare professionals are necessary to ensure they are proficient in utilizing the technology effectively and understand how it supports safety goals. Digital health technologies have the ability to significantly enhance patient safety by focusing on co-design, user-centered design, usability, and adaptability.

6.2 Patient Safety and Usability

The relationship between patient safety and usability is complex and deeply interconnected, especially in healthcare settings where digital systems such as DHTs and medical devices are used extensively. Usability, as defined by ISO 9241-11, refers to the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in a specific context (ISO-standard, 2018). In the context of healthcare, this often translates to how safely and swiftly healthcare professionals can perform tasks without errors. Patient safety is directly influenced by the usability of DHTs. Poorly designed interfaces can lead to misinterpretation of data, medication errors, or delays in treatment. Outcomes that compromise patient health. For example, if a healthcare professional struggles to navigate DHT's interface to confirm a patient's allergy before administering medication, the consequences can be severe. At the same time, efficiency, achieving the goals in less time, is often a key goal in healthcare environments, driven by resource limitations and high patient volumes. However, pushing

for efficiency can sometimes conflict with safety. For instance, reducing the number of steps in a procedure may speed up workflow but increase the risk of omitting critical checks.

This creates a competing interest between patient safety and usability, more specifically the efficiency element within usability. Enhancing efficiency may compromise patient safety if not balanced correctly, while overemphasizing safety may slow workflows to the point of inefficiency and impact the value perceived by the users. The aim should be to design and develop DHTs with high usability to allow healthcare professionals to perform tasks both quickly and safely. Well-designed interfaces support intuitive interactions, reduce cognitive load, and integrate safety checks seamlessly into workflows. Ultimately, the goal should not be to choose between efficiency and patient safety, but to design DHTs where usability supports both, allowing healthcare professionals to deliver timely, accurate, and safe care.

6.3 Practical Contribution to Patient Safety

In this section, I will discuss practical guidelines for patient safety through DHTs, as well as design approaches that influence behavior and attitudes toward improved patient safety.

6.3.1 Practical Guidelines for Patient Safety through DHTs

To ensure patient safety through digital health technologies I have summarized the design principles and ethical guidelines into six dimensions: accessible, engaging, inclusive, responsible, transparent, and valuable. They are covered in more detail in section 5.2 above. I would like to offer this list of dimensions as practical guidelines to those who are either designing and developing DHTs that ensure patient safety or those who are responsible for the purchase or funding of DHTs. This checklist could serve the designers, product managers, or project managers in a way that they could evaluate how well the artifact under scrutiny fulfills each dimension. This could allow for a systematic approach to identifying strengths and weaknesses in the artifact design. For management or even patients, the checklist could serve as a method to compare

the strengths and weaknesses of two or more artifacts.

6.3.2 Influencing Behavior and Attitudes to Improve Patient Safety

Our review of digital nudges highlights their potential in DHTs to encourage behavioral changes. These changes could, in some cases, reduce risk factors for underlying conditions or help patients better manage their health during and after treatment. Based on these insights, we strongly recommend that designers and software developers consider integrating this approach, which is readily available and has demonstrated effectiveness. In our study on patients with inflammatory bowel disease (IBD), participation was 46 percent, while for atrial fibrillation (AF) patients on a waiting list, it reached around 50 percent. The fact that only a portion of patients actively engaged led us to explore a well-established approach in patient treatment: the stages of change model. The stages of change model is a widely used framework for understanding behavior change (Prochaska and Velicer, 1997). It outlines a series of stages individuals typically go through when attempting to modify behavior. These stages are non-linear, meaning individuals can move back and forth between them or revisit earlier stages. Understanding these stages can help designers or health-care professionals tailor interventions and provide support at the appropriate phase of change (Prochaska and Velicer, 1997). See Figure 6.1 below for details on the stages of change.

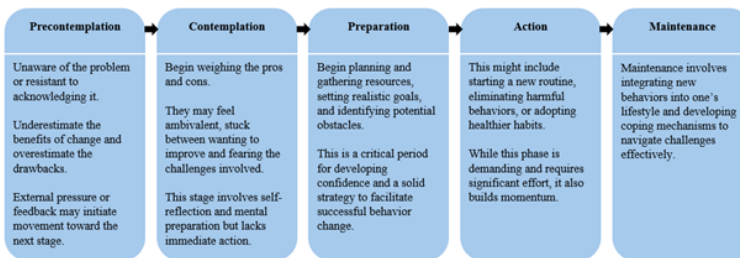


Figure 6.1: Stages of change (Prochaska and Velicer, 1997)

Research on patient behavior reveals that their perception of the pros and cons of change vary across the different stages, offering valuable insights into how individuals progress through them.

To move from precontemplation to contemplation, the benefits of making a change (the pros) must outweigh the barriers (the cons). On the other hand, transitioning from contemplation to action relies on reducing the perceived cons of change. This means intervention strategies must be carefully timed and targeted. For individuals in precontemplation, the focus should be on highlighting the advantages of change, while the barriers can be addressed later, once they reach contemplation. Progress toward action occurs when the benefits of change clearly outweigh the perceived negatives, signaling readiness for transformation (Prochaska and Velicer, 1997). To support patients through these stages, it is essential to understand the processes and principles that facilitate change. One key principle is recognizing that different approaches work best at different stages. Traditional behavioral strategies like counterconditioning or stimulus control are effective for those ready to take action but can backfire with individuals who have not yet considered change. For those in precontemplation, experiential strategies such as raising awareness (consciousness-raising) or creating emotional connections (dramatic relief) are far more effective in shifting perspectives and encouraging progress toward contemplation (Prochaska and Velicer, 1997). Encouraging patient engagement and participation has the potential to improve patient safety and quality of care.

Considering the opportunity to alter the choice architecture to encourage behavior on behalf of healthcare professionals I also considered a combination of digital nudges and applying the stages of change. Digital nudging has the potential to leverage subtle, cognitively informed design choices within DHTs to guide healthcare professionals toward desired behaviors and decisions. Through prompts, reminders, or visual cues embedded in the platform, it can support training by encouraging clinicians to explore unfamiliar features, adopt best practices, or adhere to evidence-based protocols. Timely notifications can suggest optimal actions during clinical workflows. Digital nudging has the ability to foster a gradual, user-friendly adoption of complex DHTs by aligning these nudges with learning goals, ensuring intuitive skill-building and improved proficiency over time. There might be opportunities to incorporate the stages of change into the teaching and learning strategy for healthcare professionals. The stages of change model (Prochaska and Velicer, 1997), which is usually applied to patients, offers a structured framework for engaging healthcare

professionals in training and education efforts to improve patient safety. The process would begin with the precontemplation stage, where some healthcare professionals may not yet recognize the importance of patient safety or see its relevance to their daily practices. At this stage, the focus would be on raising awareness by presenting powerful data, case studies, or real-life examples of how lapses in safety impact patient outcomes. Creating emotional and intellectual connections has the potential to initiate the shift from complacency to awareness. As healthcare professionals enter the contemplation stage, they begin acknowledging the importance of patient safety but may feel uncertainty or hesitation about how to incorporate changes. Here, educators can foster motivation by highlighting the potential benefits, better patient outcomes, less stress for healthcare professionals, and stronger provider-patient relationships. Open discussions, peer support, and access to resources can help healthcare professionals weigh the value of change. At this stage, digital nudges could be applied to the user interface of the DHTs used by healthcare professionals to promote adherence to guidelines (Nwafor et al., 2021). In the preparation stage, the focus shifts to equipping professionals with the tools, skills, and confidence needed to make changes. Detailed training on specific protocols, simulations, and collaborative exercises helps bridge the gap between intention and action. During the action stage, healthcare professionals could implement these new practices in their work. Ongoing support, feedback, and recognition for success can potentially sustain enthusiasm. This might be achieved through continuous education, regular assessments, and a supportive organizational culture that prioritizes patient safety as a core value. Progressing thoughtfully through these stages, healthcare professionals could adopt and sustain behaviors that enhance patient safety.

6.4 Theoretical Contribution to Patient Safety

In this section, I will suggest a theoretical contribution to patient safety in terms of an extension to a patient safety model and then speculate on possible implications for healthcare policy.

6.4.1 An Extension to a Patient Safety Model

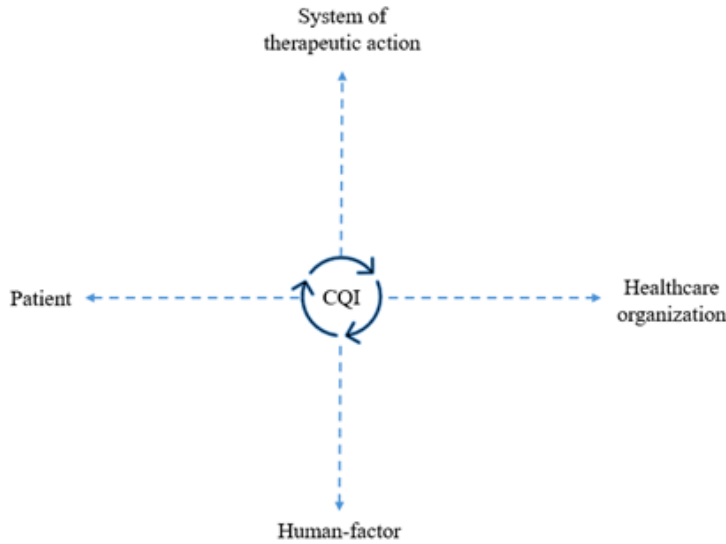


Figure 6.2: A proposed revised model of patient safety

In the theoretical background of this thesis, I introduced a patient safety model built on four key components: the patient, the healthcare professional, systems of therapeutic action, and continuous quality improvement (CQI). I aligned my studies with these four components but constrained the scope of ‘systems of therapeutic action’ to ‘digital health technologies’ (DHTs) for simplification. I propose a revised model with two intersecting axes to give greater emphasis to DHTs that operate outside traditional healthcare organizations. See Figure 6.2 above. The horizontal axis ranges from the patient at one end to the healthcare organization at the other, while the vertical axis spans from human-factor to DHTs, or after lifting the restrictive conditions to the broader systems of therapeutic action. These boundaries are represented with dotted lines, highlighting how each element influences and interacts with adjacent areas. This revised model differs from the original by shifting from three distinct “boxes” to four areas. The newly created space represents systems of therapeutic action that belong to the patient but exist outside the formal healthcare sys-

tem. CQI is a critical component of the patient safety model, which traditionally applies either to healthcare professionals or systems of therapeutic action. However, my approach extends CQI to patients as well. This perspective considers health literacy and patient engagement as measurable variables within digital solutions. Introducing performance metrics and quality indicators for patient behavior allows for the possibility of assessing outcomes, identifying areas for improvement, and enhancing patient safety through a more data-driven approach.

6.4.2 Implications for Healthcare Policy

The patient safety model primarily serves as a model expressing the relationships among concepts and constructs. In many ways, it functions like a conceptual model, a guiding structure that supports analysis and discussion. When it comes to healthcare policy, the conversation often gravitates toward challenges such as limited resources, managerial complexities, and governance issues. These factors shape the way patient safety initiatives are implemented and highlight the need for strategic approaches that balance efficiency with quality care and patient safety. The revised model can serve a valuable role in healthcare policy by allowing stakeholders to be positioned within its model. It also helps identify where priorities should be placed, distinguish what is being assessed, and analyze the resulting impact. Additionally, the model provides insight into how connections between stakeholders can be strengthened to enhance overall effectiveness.

First, developing digital health platforms with limited resources presents major challenges that impact innovation, functionality, and patient safety. Funding constraints can limit access to skilled professionals, advanced technology, and thorough testing, leading to potential gaps in usability and effectiveness. Small teams under tight deadlines may struggle to balance design, development, and user testing, risking incomplete feedback and weaker final products. Resource limitations also affect patient safety, as new features may not undergo sufficient testing or risk assessments. Backend developers, focused on in-house solutions, leave third-party digital health technologies (DHTs) at a disadvantage, even though external solutions can sometimes be more cost-effective. Given these constraints, resources must be allocated wisely to maximize benefits for both patients and healthcare profession-

als. This includes carefully evaluating third-party DHTs and conducting more frequent cost-benefit analyses when integrating new technologies into the hospital's digital health platform.

Second, the lack of organizational direction in digital transformation creates uncertainty in implementing new technologies like mobile applications for healthcare professionals. With no clear strategy, adoption depends on individual department heads, missing a unified approach to integrating smartphones into workflows. DHTs also pose managerial challenges, from resistance to change among healthcare professionals to resource constraints that complicate feature prioritization, training, and timelines. Poor resource allocation can delay projects and impact usability. Third, governance challenges are key in DHT development, as new systems often disrupt existing workflows. Clear decision-making frameworks are essential to prevent delays, misalignment, and incomplete solutions. With multiple stakeholders involved, undefined roles can slow progress and hinder adoption.

These areas can all be viewed through the lens of the hierarchy and it is important to understand where there are solutions and where the chain is broken, and the system does not work. It is necessary to go beyond technology and look at the bigger picture of public health policy. The WHO has set its guiding principle for patient safety, as mentioned in the background of this paper. Those guidelines are also the backbone of the quality policy of the National Hospital. Furthermore, the policy needs to be materialized through the efforts of designers and developers who co-design DHTs for patients and healthcare professionals.

6.5 Limitations and Future Work

The design and development of the digital health platform of the National Hospital is very complex and relies on the cooperation of different stakeholders such as healthcare professionals, developers, contractors, digital product managers, and project managers. There are many moving targets happening within the digital environment and this thesis only catches a period of a few years when the infrastructure and culture has developed over decades. This study has its limitations. First, hospitals provide a very diverse healthcare service and the processes also differ greatly between departments and specialties. In our study, we only worked

with a limited number of inpatient and outpatient departments and therefore the views and feedback expressed in this research might not be generalizable for the whole hospital. Second, similarly, our research regarding understanding and attitudes toward digital nudges was conducted on a homogeneous group of participants (teenage girls). Third, this study does not include examples of digital nudges that have been designed from scratch and applied to artifacts that are in real-world settings. Fourth, the benefits of continuous quality improvements for patients with atrial fibrillation were not created and tested to show the relationship between collecting data and improvements in patient safety. Fifth, the search for articles in the systematic literature review might have been too narrow and not include all terms that could include approaches interpreted as digital nudges. Finally, in this study, we do not refer to any concrete benchmark for patient safety other than mentioning the number of reported adverse events.

There are many ways to extend the research of this study in future work. Here are some suggestions for further explorations. First, the mobile app for healthcare professionals is still in its early stages and it would be interesting to do a follow-up analysis now that more features have been added to bedside documentation. Second, analyze healthcare professionals' understanding and attitudes toward persuasive system design such as digital nudges. Third, introduce wearables into the remote monitoring of patients with AF. Fourth, gather feedback from patients about their experience of being remotely monitored by the outpatient Department of Cardiology. Fifth, performance analytics on the data gathered for the AF registry and create quality indicators that could result in actionable insight. Sixth, start collecting data from patients who are undergoing other surgeries than ablations and also start measuring quality-of-life indicators from patients. This could lay the foundation for standardized quality indicators. Finally, apply the dimensions derived from this research to actual DHTs and mark each dimension on a scale from 0-10. Evaluate the benefits and drawbacks of that approach.

Chapter 7

Conclusion

The research presented in this thesis underscores the transformative potential of digital health technologies (DHTs) in improving patient safety. Through an iterative, co-design process involving healthcare professionals, experts, and developers, we have demonstrated that DHTs can enhance clinical documentation, support continuous quality improvement, and influence behavior through digital nudges. The findings illustrate that patient safety is not simply a byproduct of technological advancement but rather a deliberate outcome achieved through thoughtful design, collaboration, and continuous evaluation.

A central theme emerging from this research is that successful DHT development requires an interdisciplinary approach that integrates user-centered design (UCD) principles. The involvement of healthcare professionals from the early stages of development ensures that these technologies align with real-world clinical workflows and do not introduce new inefficiencies or safety risks. The studies on mobile applications and digital health programs illustrate how co-design can lead to solutions that seamlessly fit into clinical environments, improving documentation, data collection, and patient engagement. The thesis also highlights the power of behavior-influencing design in healthcare, particularly through digital nudging. Digital nudges can be instrumental in bridging the gap between intention and action by subtly guiding both patients and healthcare professionals toward safer and more effective health behaviors. The research findings on patient engagement with digital health programs suggest that those who actively par-

ticipate often report better health outcomes, reinforcing the idea that behavioral design strategies can be leveraged to maximize the impact of DHTs.

This research offers a theoretical contribution by proposing an extension to an existing patient safety model. This revised model acknowledges the role of DHTs operating outside traditional healthcare institutions and positions patient engagement as a measurable component of continuous quality improvement (CQI). The model has the potential to provide a more comprehensive framework for assessing and enhancing safety in digital healthcare environments by integrating patient behavior metrics.

From a practical standpoint, the research outlines six key dimensions: accessible, engaging, inclusive, responsible, transparent, and valuable. They can serve as practical guidelines for designing and evaluating DHTs with patient safety in mind. These dimensions provide a structured approach for developers, product managers, and healthcare organizations to assess the strengths and weaknesses of digital health solutions before implementation. Moreover, they offer a foundation for policymakers to prioritize patient safety in digital transformation strategies, ensuring that DHTs align with both institutional goals and broader public health objectives.

To mention some of the limitations, the research was conducted within a specific hospital setting, involving a select group of participants, which may limit generalizability. Additionally, while digital nudges were explored conceptually, their real-world application in clinical settings remains an area for future investigation. Further research could extend the findings by incorporating patient perspectives, analyzing long-term outcomes of digital interventions, and exploring the integration of wearable technology in remote monitoring. Ultimately, this thesis reinforces the idea that patient safety in the digital age is not a static achievement but an evolving goal that requires continuous innovation, adaptation, and collaboration. Designing DHTs that prioritize usability, integration, and behavioral insights, can create healthcare environments that are not only technologically advanced but also fundamentally safer and more effective for patients and professionals alike. The journey toward safer healthcare through digital transformation is ongoing, and this research serves as a stepping stone toward a future where technology and human-centered design work hand in hand to improve patient outcomes.

Bibliography

- Abras, C., Maloney-Krichmar, D., and Preece, J. (2004). User-centered design. *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, 37(4), 445-456.
- Alsabri, M., Boudi, Z., Lauque, D., Dias, R. D., Whelan, J. S., Östlundh, L., ... and Bellou, A. (2022). Impact of teamwork and communication training interventions on safety culture and patient safety in emergency departments: a systematic review. *Journal of patient safety*, 18(1), e351-e361.
- Andersen, T. O. (2019). Large-scale and long-term co-design of digital health. *Interactions*, 26(5), 74-77.
- Andersen, T. O., Kanstrup, A. M., and Yndigegn, S. L. (2018). Three living labs in Denmark: Challenges with co-design and implementation of health IT. *In Proceedings from the 16th Scandinavian Conference on Health Informatics 2018 Aalborg, Denmark August 28-29, 2018* (pp. 1-6). Linköping University Electronic Press.
- Arnar, D. O., Oddsson, S. J., Gunnarsdottir, T., Gudlaugsdottir, G. J., Gudmundsson, E. F., Ketilsdóttir, A., ... and Thorgeirsson, T. (2022). Improving outpatient care for heart failure through digital innovation: a feasibility study. *Pilot and Feasibility Studies*, 8(1), 242.
- Arno, A., and Thomas, S. (2016). The efficacy of nudge theory strategies in influencing adult dietary behaviour: a systematic review and meta-analysis. *BMC public health*, 16(1), 1-11.
- Atkinson, B. M. (2006, May). Captology: A critical review. *In International conference on persuasive technology* (pp. 171-182). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Austin, J. L. (1962). *How to do things with words*. Oxford: Clarendon.
- Avital, M. and Te'eni, D. (2009). From Generative Fit to Generative Capacity: Exploring an emerging dimension of information

systems design and taskperformance, *Information Systems Journal* 19(4): 345–367

Baashar, Y., Alhussian, H., Patel, A., Alkawsi, G., Alzahrani, A. I., Alfarraj, O., and Hayder, G. (2020). Customer relationship management systems (CRMS) in the healthcare environment: A systematic literature review. *Computer Standards and Interfaces*, 71, 103442.

Baron, J., and Ritov, I. (1994). Reference points and omission bias. *Organizational behavior and human decision processes*, 59(3), 475-498.

Baxter, G., and Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with computers*, 23(1), 4-17.

Beleffi, E., Mosconi, P., and Sheridan, S. (2021). The patient journey. *Textbook of patient safety and clinical risk management*, 117-127.

Berdichevsky, D., and Neuenschwander, E. (1999). Toward an ethics of persuasive technology. *Communications of the ACM*, 42(5), 51-58.

Bergram, K., Djokovic, M., Bezençon, V., and Holzer, A. (2022, April). The digital landscape of nudging: A systematic literature review of empirical research on digital nudges. *In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).

Bird, M., McGillion, M., Chambers, E. M., Dix, J., Fajardo, C. J., Gilmour, M., ... and Carter, N. (2021). A generative co-design framework for healthcare innovation: development and application of an end-user engagement framework. *Research Involvement and Engagement*, 7, 1-12.

Borges do Nascimento, I. J., Abdulazeem, H., Vasanthan, L. T., Martinez, E. Z., Zucoloto, M. L., Østengaard, L., ... and Novillo-Ortiz, D. (2023). Barriers and facilitators to utilizing digital health technologies by healthcare professionals. *NPJ digital medicine*,

6(1), 161.

Bostrom, R. P., and Heinen, J. S. (1977). MIS problems and failures: a socio-technical perspective, part II: the application of socio-technical theory. *MIS quarterly*, 11-28.

Brooke, J. (1996). SUS: A quick and dirty usability scale. *Usability Evaluation in Industry*.

Bygstad, B. (2017). Generative innovation: a comparison of lightweight and heavyweight IT. *Journal of information technology*, 32(2), 180-193.

Byrne, J., and Humble, Á. M. (2007). An introduction to mixed method research. *Atlantic research centre for family-work issues*, 1, 1-4.

Caraban, A., Karapanos, E., Gonçalves, D., and Campos, P. (2019, May). 23 ways to nudge: A review of technology-mediated nudging in human-computer interaction. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 1-15).

Carayon, P., Wooldridge, A., Hoonakker, P., Hundt, A. S., and Kelly, M. M. (2020). SEIPS 3.0: Human-centered design of the patient journey for patient safety. *Applied ergonomics*, 84, 103033.

Carmichael, L., Poirier, S. M., Coursaris, C. K., Léger, P. M., and Sénécal, S. (2022). Users' information disclosure behaviors during interactions with Chatbots: The effect of information disclosure nudges. *Applied Sciences*, 12(24), 12660.

Cheraghi, R., Ebrahimi, H., Kheibar, N., and Sahebihagh, M. H. (2023). Reasons for resistance to change in nursing: an integrative review. *BMC nursing*, 22(1), 310.

Cho, I., and Bates, D. W. (2018). Behavioral economics interventions in clinical decision support systems. *Yearbook of medical informatics*, 27(1), 114.

Cronholm, S., and Göbel, H. (2019). Evaluation of action design

- research. *Scandinavian journal of information systems*, 31(2), 2.
- Dahalan, F., Alias, N., and Shaharom, M. S. N. (2024). Gamification and game based learning for vocational education and training: A systematic literature review. *Education and Information Technologies*, 29(2), 1279-1317.
- Dal Mas, F., Massaro, M., Rippa, P., and Secundo, G. (2023). The challenges of digital transformation in healthcare: An interdisciplinary literature review, framework, and future research agenda. *Technovation*, 123, 102716.
- Davis, J. (2009, April). Design methods for ethical persuasive computing. In *Proceedings of the 4th International Conference on Persuasive Technology* (pp. 1-8).
- Ellingsen, G., Grisot, M., Hertzum, M., and Islind, A. S. (2024). Implementing Electronic Health Records—Objectives, Obstacles, Outcomes. European Conference on *Computer-Supported Cooperative Work*.
- Emanuel, L., Berwick, D., Conway, J., Combes, J., Hatlie, M., Leape, L., ... and Walton, M. (2009). What exactly is patient safety? *Journal of Medical Regulation*, 95(1), 13-24.
- Eriksen, M. B., and Frandsen, T. F. (2018). The impact of patient, intervention, comparison, outcome (PICO) as a search strategy tool on literature search quality: a systematic review. *Journal of the Medical Library Association: JMLA*, 106(4), 420.
- Erlingsdottir, H. Y., Ketilsdottir, A., Hendriks, J. M., and Ingadottir, B. (2023). Disease-Related Knowledge and Need for Revision of Care for Patients with Atrial Fibrillation: A Cross Sectional Study. *Patient preference and adherence*, 2621-2630.
- Esmailzadeh, P., Dharanikota, S., and Mirzaei, T. (2024). The role of patient engagement in patient-centric health information exchange (HIE) initiatives: an empirical study in the United States. *Information Technology and People*, 37(2), 521-552.
- Farrall, A., Taylor, J., Ainsworth, B., and Alexander, J. (2023,

April). Manifesting breath: Empirical evidence for the integration of shape-changing biofeedback-based artefacts within digital mental health interventions. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-14).

Feldman, S. S., Buchalter, S., and Hayes, L. W. (2018). Health information technology in healthcare quality and patient safety: literature review. *JMIR medical informatics*, 6(2), e10264.

Flott, K., Maguire, J., and Phillips, N. (2021). Digital safety: the next frontier for patient safety. *Future Healthcare Journal*, 8(3), e598-e601.

Fogg, B. J. (2003). Persuasive technology: using computers to change what we think and do. *Ubiquity*, 2002 (December), 2.

Giebel, G. D., Speckemeier, C., Abels, C., Plescher, F., Borchers, K., Wasem, J., ... and Neusser, S. (2023). Problems and barriers related to the use of digital health applications: scoping review. *Journal of Medical Internet Research*, 25, e43808.

Goldstein, N. J., Cialdini, R. B., and Griskevicius, V. (2008). A room with a viewpoint: Using social norms to motivate environmental conservation in hotels. *Journal of consumer Research*, 35(3), 472-482.

Graneheim, U. H., and Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse education today*, 24(2), 105-112.

Grindell, C., Coates, E., Croot, L., and O’Cathain, A. (2022). The use of co-production, co-design and co-creation to mobilise knowledge in the management of health conditions: a systematic review. *BMC Health Services Research*, 22(1), 877.

GS1 UK (2020). A scan of the benefits: the Scan4Safety evidence report <https://healthcare.gs1uk.org/scan4safety/.pdf> [Accessed 9 Feb 2025]

Gudmundsson, G. H., Mészáros, J., Björnsdóttir, Á. E., Ámundadóttir, M. L., Thorvardardóttir, G. E., and Magnúsdóttir, E. Eval-

uating the feasibility of a digital therapeutic program for patients with cancer during active treatment: pre-post interventional study. *JMIR Form Res.* 2022; 6 (10): e39764.

Habermas, J. (1993). Justification and application: Remarks on discourse ethics.

Haj-Bolouri, A., Purao, S., Rossi, M., and Bernhardsson, L. (2017). Action design research as a method-in-use: problems and opportunities.

Hall, M. G., Marteau, T. M., Sunstein, C. R., Ribisl, K. M., Noar, S. M., Orlan, E. N., and Brewer, N. T. (2018). Public support for pictorial warnings on cigarette packs: an experimental study of US smokers. *Journal of behavioral medicine*, 41, 398-405.

Halpern, S. D., Ubel, P. A., and Asch, D. A. (2007). Harnessing the power of default options to improve health care. *New England Journal of Medicine*, 357(13), 1340-1344.

Haleem, A., Javaid, M., Singh, R. P., and Suman, R. (2021). Telemedicine for healthcare: Capabilities, features, barriers, and applications. *Sensors international*, 2, 100117.

Harrison, A. M., Siwani, R., Pickering, B. W., and Herasevich, V. (2019). Clinical impact of intraoperative electronic health record downtime on surgical patients. *Journal of the American Medical Informatics Association*, 26(10), 928-933.

Hassenzahl, M., Burmester, M., and Koller, F. (2003). AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. *Mensch and Computer 2003: Interaktion in Bewegung*, 187-196.

Heavin, C., and Power, D. J. (2018). Challenges for digital transformation—towards a conceptual decision support guide for managers. *Journal of Decision Systems*, 27(sup1), 38-45.

Henni, S. H., Maurud, S., Fuglerud, K. S., and Moen, A. (2022). The experiences, needs and barriers of people with impairments related to usability and accessibility of digital health solutions,

levels of involvement in the design process and strategies for participatory and universal design: a scoping review. *BMC public health*, 22(1), 35.

Hickmann, E., Richter, P., and Schlieter, H. (2022). All together now—patient engagement, patient empowerment, and associated terms in personal healthcare. *BMC health services research*, 22(1), 1116.

Hilmarsdóttir, E., Sigurðardóttir, Á. K., and Arnardóttir, R. H. (2021). A digital lifestyle program in outpatient treatment of type 2 diabetes: a randomized controlled study. *Journal of Diabetes Science and Technology*, 15(5), 1134-1141.

Hoffmann, C., and Thommes, K. (2020). Can digital feedback increase employee performance and energy efficiency in firms? Evidence from a field experiment. *Journal of Economic Behavior and Organization*, 180, 49-65.

Hummel, D., and Maedche, A. (2019). How effective is nudging? A quantitative review on the effect sizes and limits of empirical nudging studies. *Journal of Behavioral and Experimental Economics*, 80, 47-58

Ingimarsdóttir, I. J., Hansen, J. S., Bergmann, H. M., and Einarsson, H. (2024). The Icelandic Heart Failure Registry—A nationwide assessment tool for HF care and intervention in HF treatment. *ESC Heart Failure*, 11(6), 4081-4091.

Irizarry, T., DeVito Dabbs, A., and Curran, C. R. (2015). Patient portals and patient engagement: a state of the science review. *Journal of medical Internet research*, 17(6), e148.

Islam, M. S., Hasan, M. M., Wang, X., Germack, H. D., and Noor-E-Alam, M. (2018, May). A systematic review on healthcare analytics: application and theoretical perspective of data mining. *In Healthcare* (Vol. 6, No. 2, p. 54). MDPI.

Islind, A. S. (2018). Platformization: co-designing digital platforms in practice (Doctoral dissertation, University West).

Islind, A. S. (2022). Co-design as a driver of change. *Performance Paradigm*, (17), 166-180.

ISO-standard (2018) - <https://www.iso.org/obp/ui/iso:std:iso:9241:-11:ed-2:v1:en>. Retrieved 20.05.2025

Jabin, M. S. R., Pan, D., and Nilsson, E. (2024). Characterizing patient details-related challenges from health information technology-related incident reports from Swedish healthcare. *Frontiers in Digital Health*, 6, 1260521.

Jachimowicz, J. M., Duncan, S., Weber, E. U., and Johnson, E. J. (2019). When and why defaults influence decisions: A meta-analysis of default effects. *Behavioural Public Policy*, 3(2), 159-186.

Jóhannsdóttir, L. G., Sigurðardóttir, S. G., Óskarsdóttir, M., and Islind, A. S., (2024). Digital Nudging in Digital Health Technologies: A Systematic Review. Under review at *Health and Technology*

Johansson, V., Islind, A. S., Lindroth, T., Angenete, E., and Gellerstedt, M. (2021). Online communities as a driver for patient empowerment: Systematic review. *Journal of medical Internet research*, 23(2), e19910.

Johnson, E. J., and Goldstein, D. (2003). Do defaults save lives? ed: *American Association for the Advancement of Science*.

Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American economic review*, 93(5), 1449-1475.

Kahneman, D., Lovallo, D., and Sibony, O. (2011). Before you make that big decision. *Harvard business review*, 89(6), 50-60.

Karni, L., Dalal, K., Memedi, M., Kalra, D., and Klein, G. O. (2020). Information and communications technology-based interventions targeting patient empowerment: Framework development. *Journal of medical Internet research*, 22(8), e17459.

- Khalifa, M., and Zabani, I. (2016). Utilizing health analytics in improving the performance of healthcare services: A case study on a tertiary care hospital. *Journal of Infection and Public Health*, 9(6), 757-765.
- Khalifa, M. (2018). Health analytics types, functions and levels: a review of literature. *Data, Informatics and Technology: An Inspiration for Improved Healthcare*, 137-140.
- Kight, R., and Gram-Hansen, S. B. (2019). Do ethics matter in persuasive technology?. In *Persuasive Technology: Development of Persuasive and Behavior Change Support Systems: 14th International Conference, PERSUASIVE 2019, Limassol, Cyprus, April 9–11, 2019, Proceedings 14* (pp. 143-155). Springer International Publishing.
- Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., and Roig-Tierno, N. (2021). Digital transformation: An overview of the current state of the art of research. *Sage Open*, 11(3), 21582440211047576.
- Kraus, S., Schiavone, F., Pluzhnikova, A., and Invernizzi, A. C. (2021). Digital transformation in healthcare: Analyzing the current state-of-research. *Journal of Business Research*, 123, 557-567.
- Lane, D.A. (2011). Complexity and Innovation Dynamics, in C. Antonelli (ed.) *Handbook on the Economic Complexity of Technological Change*, Cheltenham,UK: Edward Elgar Publishing
- Ledderer, L., Kjær, M., Madsen, E. K., Busch, J., and Fage-Butler, A. (2020). Nudging in public health lifestyle interventions: a systematic literature review and metanalysis. *Health Education and Behavior*, 47(5), 749-764.
- Leonardi, P. (2011). When Flexible Routines Meet Flexible Technologies: Affordance, Constraint, and the Imbrication of Human and Material Agencies, *Management Information Systems Quarterly* 35(1): 147–167.
- Lembcke, T. B., Engelbrecht, N., Brendel, A. B., Herrenkind, B.,

and Kolbe, L. M. (2019). Towards a Unified Understanding of Digital Nudging by Addressing its Analog Roots. In *PACIS* (p. 123).

Li, J., Goerlandt, F., and Reniers, G. (2021). An overview of scientometric mapping for the safety science community: Methods, tools, and framework. *Safety Science*, 134, 105093.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... and Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of internal medicine*, 151(4), W-65.

Lintern, G., and Motavalli, A. (2018). Healthcare information systems: the cognitive challenge. *BMC medical informatics and decision making*, 18, 1-10.

Mahajan, S., Lu, Y., Spatz, E. S., Nasir, K., and Krumholz, H. M. (2021). Trends and predictors of use of digital health technology in the United States. *The American journal of medicine*, 134(1), 129-134.

Maqbool, B., and Herold, S. (2023). Potential effectiveness and efficiency issues in usability evaluation within digital health: A systematic literature review. *Journal of Systems and Software*, 111881.

Masoumian Hosseini, M., Masoumian Hosseini, S. T., Qayumi, K., Hosseinzadeh, S., and Sajadi Tabar, S. S. (2023). Smartwatches in healthcare medicine: assistance and monitoring; a scoping review. *BMC Medical Informatics and Decision Making*, 23(1), 248.

Matheus, R., Janssen, M., and Janowski, T. (2021). Design principles for creating digital transparency in government. *Government Information Quarterly*, 38(1), 101550.

Mathews, S. C., McShea, M. J., Hanley, C. L., Ravitz, A., Labrique, A. B., and Cohen, A. B. (2019). Digital health: a path to validation. *NPJ digital medicine*, 2(1), 38.

McCaffery, K. J., Smith, S. K., and Wolf, M. (2010). The chal-

lenge of shared decision making among patients with lower literacy: a framework for research and development. *Medical Decision Making*, 30(1), 35-44.

McCarthy, B., Fitzgerald, S., O'Shea, M., Condon, C., Hartnett-Collins, G., Clancy, M., ... and Savage, E. (2019). Electronic nursing documentation interventions to promote or improve patient safety and quality care: A systematic review. *Journal of nursing management*, 27(3), 491-501.

McDonald, K. M., Romano, P. S., Geppert, J., Davies, S. M., Duncan, B. W., Shojania, K. G., and Hansen, A. (2010). Measures of patient safety based on hospital administrative data-the patient safety indicators.

McDonald, P. L., Foley, T. J., Verheij, R., Braithwaite, J., Rubin, J., Harwood, K., ... and Van Der Wees, P. J. (2024). Data to knowledge to improvement: creating the learning health system. *bmj*, 384.

McLaughlin, C. P., and Kaluzny, A. D. (2006). *Continuous quality improvement in health care: theory, implementations, and applications*. Jones and Bartlett Learning.

Meske, C., and Amojó, I. (2020). Ethical guidelines for the construction of digital nudges. *arXiv preprint arXiv:2003.05249*.

Meske, C., Amojó, I., Poncette, A. S., and Balzer, F. (2019, July). The potential role of digital nudging in the digital transformation of the healthcare industry. In *International Conference on Human-Computer Interaction* (pp. 323-336). Cham: Springer International Publishing.

Mettler, T., and Stepanovic, S. (2023). Acceptable nudge strategies to incentivize the use of wearables and physiolytics at work: A Q-methodology examination. *Journal of Information Technology*, 02683962231173706.

Mirsch, T., Lehrer, C., and Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. *Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017)*, 634-

648.

Mirsch, T., Lehrer, C., and Jung, R. (2018). Making digital nudging applicable: The digital nudge design method.

Mobekk, H., and Stokke, L. (2020). Nudges emphasizing social norms increased hospital visitors' hand sanitizer use. *Behavioral Science and Policy*, 6(2), 51-57.

Muscat, D. M., Shepherd, H. L., Nutbeam, D., Trevena, L., and McCaffery, K. J. (2021). Health literacy and shared decision-making: exploring the relationship to enable meaningful patient engagement in healthcare. *Journal of general internal medicine*, 36, 521-524.

Möllenkamp, M., Zeppernick, M., and Schreyögg, J. (2019). The effectiveness of nudges in improving the self-management of patients with chronic diseases: a systematic literature review. *Health Policy*, 123(12), 1199-1209.

Nyström, M. E., Karlton, J., Keller, C., and Andersson Gäre, B. (2018). Collaborative and partnership research for improvement of health and social services: researcher's experiences from 20 projects. *Health research policy and systems*, 16, 1-17.

NHS (2021). Plan, Do, Study, Act (PDSA) cycles and the model for improvement. *UK: NHS England*.

NHS (2025), <https://digital.nhs.uk/services/clinical-safety>

Nwafor, O., Singh, R., Collier, C., DeLeon, D., Osborne, J., and DeYoung, J. (2021). Effectiveness of nudges as a tool to promote adherence to guidelines in healthcare and their organizational implications: A systematic review. *Social Science and Medicine*, 286, 114321.

Oddsson, S. J., Gunnarsdottir, T., Jóhannsdóttir, L. G., Amundadóttir, M. L., Frimannsdóttir, A., Molander, P., Ylanne, A. K., Islind, A. S., Óskarsdóttir, M. and Thorgeirsson, T. (2023). A new digital health program for patients with inflammatory bowel disease: preliminary program evaluation. *JMIR Formative Research*, 7(1),

e39331.

Olakotan, O. O., and Mohd Yusof, M. (2021). The appropriateness of clinical decision support systems alerts in supporting clinical workflows: a systematic review. *Health informatics journal*, 27(2), 14604582211007536.

Oldham, P. D. (1963). On the analysis of repeated measurements of the same subjects. *Journal of Chronic Diseases*, 16(5), 449-450.

Osman Andersen, T., Kanstrup, A. M., and Yndigegn, S. L. (2018). Three living labs in Denmark: Challenges with co-design and implementation of health IT. I A. Bygholm, L. Pape-Haugaard, K. Niss, O. Hejlesen, and C. Zhou (red.). In *Proceedings from The 16th Scandinavian Conference on Health Informatics 2018 Aalborg* (pp. 28-29).

Patel, M. S., Volpp, K. G., and Asch, D. A. (2018). Nudge units to improve the delivery of health care. *New England Journal of Medicine*, 378(3), 214-216.

Pedersen, A. M., and Bossen, C. (2024). Cultivating Data Practices Across Boundaries: How Organizations Become Data-driven. *Computer Supported Cooperative Work (CSCW)*, 1-45.

Presthus, W., and Bygstad, B. (2014). Strawberry analysis: Writing a paper-based PhD. In *Norsk konferanse for organisasjoners bruk av IT* (Vol. 22, No. 1).

Prochaska, J. O., and Velicer, W. F. (1997). The transtheoretical model of health behavior change. *American journal of health promotion*, 12(1), 38-48.

Purohit, A. K., Schöbel, S., Bill, O., and Holzer, A. (2023). Nudging to change, the role of digital health. In *Digital health: From assumptions to implementations* (pp. 137-154). Cham: Springer International Publishing.

Richardson, S., Lawrence, K., Schoenthaler, A. M., and Mann, D. (2022). A framework for digital health equity. *NPJ digital medicine*, 5(1), 119.

Rosenlund, M., Kinnunen, U. M., and Saranto, K. (2023). The use of digital health services among patients and citizens living at home: scoping review. *Journal of Medical Internet Research*, 25, e44711.

Ropohl, G. (1999). Philosophy of socio-technical systems. *Society for Philosophy and Technology Quarterly Electronic Journal*, 4(3), 186-194.

Salovaara, A., Lyytinen, K., and Penttinen, E. (2019). High reliability in digital organizing: Mindlessness, the frame problem, and digital operations. *MIS quarterly*.

Sankaran, S., Frederix, I., Haesen, M., Dendale, P., Luyten, K., and Coninx, K. (2016, June). A grounded approach for applying behavior change techniques in mobile cardiac tele-rehabilitation. In *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments* (pp. 1-8).

Sauro, J., and Lewis, J. R. (2016). Quantifying the user experience: Practical statistics for user research. Morgan Kaufmann.

Sawesi, S., Rashrash, M., Phalakornkule, K., Carpenter, J. S., and Jones, J. F. (2016). The impact of information technology on patient engagement and health behavior change: a systematic review of the literature. *JMIR medical informatics*, 4(1), e4514.

Schneider, C., Weinmann, M., and Vom Brocke, J. (2018). Digital nudging: guiding online user choices through interface design. *Communications of the ACM*, 61(7), 67-73

Schmidt, U., and Zank, H. (2005). What is loss aversion?. *Journal of risk and uncertainty*, 30, 157-167.

Schmitz, L., Richert, E., Arnardottir, E. S., and Islind, A. S. (2024). Nudging with Dignity: A Critical Examination of when and how to use Digital Nudging. *Scandinavian Conference of Information Systems*.

Schwartz, J., Mochon, D., Wyper, L., Maroba, J., Patel, D., and

- Ariely, D. (2014). Healthier by precommitment. *Psychological science*, 25(2), 538-546.
- Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., and Lindgren, R. (2011). Action design research. *MIS quarterly*, 37-56.
- Severinsen, G. H., Silsand, L., Malm Nicolaisen, K., Pedersen, R., and Ellingsen, G. (2022). Introducing Lightweight IT—A Way to Build Flexibility for Healthcare Organizations?. In *Challenges of Trustable AI and Added-Value on Health* (pp. 199-203). IOS Press.
- Sharma, A., Harrington, R. A., McClellan, M. B., Turakhia, M. P., Eapen, Z. J., Steinhubl, S., ... and Peterson, E. D. (2018). Using digital health technology to better generate evidence and deliver evidence-based care. *Journal of the American College of Cardiology*, 71(23), 2680-2690.
- Sharifi, S., Zahiri, M., Dargahi, H., and Faraji-Khiavi, F. (2021). Medical record documentation quality in the hospital accreditation. *Journal of education and health promotion*, 10(1), 76.
- Sheehan, P., Joy, A., Fleming, A., Vosper, H., and McCarthy, S. (2022). Human factors and patient safety in undergraduate healthcare education: A systematic review. *Human factors in healthcare*, 2, 100019.
- Singh, H., and Sittig, D. F. (2016). Measuring and improving patient safety through health information technology: The Health IT Safety Framework. *BMJ quality and safety*, 25(4), 226-232.
- Smith, K. A., Blease, C., Faurholt-Jepsen, M., Firth, J., Van Daele, T., Moreno, C., ... and Cipriani, A. (2023). Digital mental health: challenges and next steps. *BMJ Ment Health*, 26(1).
- Spahn, A. (2011). And lead us (not) into persuasion...? Persuasive technology and the ethics of communication. *Science and engineering ethics*, 18, 633-650.
- Sunstein, C. R. (2014). Nudging: a very short guide. *Journal of Consumer Policy*, 37, 583-588.

Stoumpos, A. I., Kitsios, F., and Talias, M. A. (2023). Digital transformation in healthcare: technology acceptance and its applications. *International journal of environmental research and public health*, 20(4), 3407.

Sujan, M., Scott, P., and Cresswell, K. (2020). Digital health and patient safety: technology is not a magic wand. *Health informatics journal*, 26(4), 2295-2299.

Sørensen, C., de Reuver, M. and Basole, R.C. (2015). Mobile Platforms and Ecosystems, *Journal of Information Technology* 30(3): 195–197.

Tay, B. S., Edney, S. M., Brinkworth, G. D., Cox, D. N., Wiggins, B., Davis, A., ... and Ryan, J. C. (2021). Co-design of a digital dietary intervention for adults at risk of type 2 diabetes. *BMC public health*, 21, 1-12.

Thaler, R. H., and Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. Yale University Press.

Thorgeirsson, T., and Kawachi, I. (2013). Behavioral economics: merging psychology and economics for lifestyle interventions. *American journal of preventive medicine*, 44(2), 185-189.

Thorgeirsson, T., Torfadottir, J. E., Egilsson, E., Oddsson, S., Gunnarsdottir, T., Aspelund, T., ... and Bjarnason, R. G. (2022). Randomized trial for weight loss using a digital therapeutic application. *Journal of diabetes science and technology*, 16(5), 1150-1158.

Tu, Y. K., and Gilthorpe, M. S. (2007). Revisiting the relation between change and initial value: a review and evaluation. *Statistics in medicine*, 26(2), 443-457.

Turner, J. R., and Baker, R. M. (2019). Complexity theory: An overview with potential applications for the social sciences. *Systems*, 7(1), 4.

Tversky, A., and Kahneman, D. (1974). Judgment under uncer-

- tainty: Heuristics and biases. *science*, 185(4157), 1124-1131.
- Tversky, A., and Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The quarterly journal of economics*, 106(4), 1039-1061.
- Valdez, A. C., Ziefle, M., and Sedlmair, M. (2017). Priming and anchoring effects in visualization. *IEEE transactions on visualization and computer graphics*, 24(1), 584-594.
- Vegni, E., Gilardi, D., Bonovas, S., Corrà, B. E., Menichetti, J., Leone, D., ... and Fiorino, G. (2019). Illness perception in inflammatory bowel disease patients is different between patients with active disease or in remission: a prospective cohort study. *Journal of Crohn's and Colitis*, 13(4), 417-423.
- Ventola CL. Mobile devices and apps for health care professionals: uses and benefits. *P T* 2014 May;39(5):356-364
- Vincent, C. (2011). *Patient safety*. John Wiley and Sons.
- Visescu, I., Jóhannsdóttir, L. G., Islind A. S., (2024) Whistling in the Dark: Inability to Recognize Dark Patterns and Lack of Concern Amongst Teenagers. *Presentation at the ItAIS 2024 conference, which will be held in Piacenza on October 11th-12th, 2024.*
- Voegtlin, C., Scherer, A. G., Stahl, G. K., and Hawn, O. (2022). Grand societal challenges and responsible innovation. *Journal of Management Studies*, 59(1), 1-28.
- Weick, K. E., and Sutcliffe, K. M. (2015). *Managing the unexpected: Sustained performance in a complex world*. John Wiley and Sons.
- Weinmann, M., Schneider, C., and Brocke, J. V. (2016). Digital nudging. *Business and Information Systems Engineering*, 58, 433-436.
- Whitehead, L., and Seaton, P. (2016). The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. *Journal of medical Internet re-*

search, 18(5), e97.

World Health Organization. (2021). Global patient safety action plan 2021-2030: towards eliminating avoidable harm in health care. *World Health Organization*.

Yeung, A. W. K., Torkamani, A., Butte, A. J., Glicksberg, B. S., Schuller, B., Rodriguez, B., Ting, D. S., Bates, D., Schaden, E., and Peng, H. (2023). The promise of digital healthcare technologies. *Frontiers in Public Health*, 11, 1196596.

Yoo, Y. (2013). The Tables have Turned: How can the information systems field contribute to technology and innovation management research? *Journal of the Association for Information Systems* 14(5): 227–236

Zhang, Y., Bellamy, R. K., and Kellogg, W. A. (2015, April). Designing information for remediating cognitive biases in decision-making. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems* (pp. 2211-2220)

Appendix A

Publications

Appendix B

Co-Designing Digital Health Applications: Unravelling the Importance of Mobile Bedside Documentation Practices

Co-Designing Digital Health Applications: Unravelling the Importance of Mobile Bedside Documentation Practices

Completed Research Full Paper

Lilja Guðrún Jóhannsdóttir

Reykjavík University
liljaj20@ru.is

Anna Halldóra N. Snorradóttir

Reykjavík University
annan23@ru.is

Adeline Tracz

Landspítali Hospital
adeline@landspitali.is

María Óskarsdóttir

Reykjavík University
mariaoskars@ru.is

Anna Sigríður Islind

Reykjavík University
annasi@ru.is

Abstract

An estimated one in ten patients experiences an adverse event while receiving hospital care in a high-income country. Good clinical documentation is one of the cornerstones of patient safety. However, in the fast-paced and unpredictable environment of healthcare professionals, there remain challenges for real-time bedside documentation. We improve upon these challenges through digital transformation with a digital mobile application design. We identify the benefits and drawbacks of the desktop format in comparison to the digital mobile application for healthcare professionals in an empirical study based on an action design research project. The main contributions consist of five design guidelines: (i) seamless log-in/out process, (ii) utilizing scanning technologies, (iii) compatibility with other solutions, (iv) sufficient photo quality and security, and (v) comprehensive bedside documentation. Furthermore, we propose a mobile application design for digital mobile bedside documentation applications that follows these design guidelines.

Keywords

Digital Transformation, Patient Safety, Bedside Documentation, Information Systems.

Introduction

Digital transformation can improve patient safety by supporting better clinical documentation practices in healthcare. First, accurate documentation helps ensure continuity of care and provides a comprehensive record of a patient's condition, treatments, and responses, which can prevent errors and improve patient safety (McCarthy et al., 2019). Second, proper documentation facilitates clear communication among healthcare team members and ensures that all members of the team are informed about a patient's status and care plan (Asmirajanti et al., 2019). Third, detailed documentation allows for the evaluation of the quality of care delivered and helps in identifying gaps in care and areas for improvement, aiding in the development of better practices, protocols, and education (Pine et al., 2023). In hospitals, there remain structural challenges, such as not enough central stationary desktops available for all healthcare

professionals to comply with documentation standards, or the equipment might not be best suited for photo documentation. In the fast-paced and unpredictable environment of healthcare professionals there also remain challenges for real-time bedside documentation leading to documentation at the end of the shift that could be subject to memory bias. Empirically, we investigate the introduction of a new mobile application designed and developed for healthcare professionals as an extension to the patient management system, to improve documentation by allowing bedside recording in real-time. Lightweight information technology (IT) such as mobile applications has provided users with instant value for improving the workflows of healthcare professionals without the need for demanding and comprehensive reorganization of work practices (Severinsen et al. 2022). The mobile application features two key functionalities for improving patient safety. Firstly, *security check* for inpatients, which facilitates either a start of the shift checklist that a healthcare professional answers while observing the conditions of a patient at the beginning of each shift, or a regular checklist that a healthcare professional answers at fixed intervals during a shift. Secondly, *photo documentation* enables clinical photo documentation through the mobile application, feeding the data directly into the electronic health records (EHRs). The motivations behind photo documentation in clinical settings are various. Photos are taken to document the development of healing wounds or other visible symptoms, to share progress with specialists who might not be on-site or currently available, for educational purposes, and to receive consultations. The photos also become part of patients' medical health records which belong to the patients and are available to them on request. These two features of the mobile application are designed to encourage better documentation, support enhanced patient safety, and maintain a history of patient symptoms. The mobile application design and development started in May 2022 and has continued with an iterative approach.

This paper presents an action design research project to digitally transform bedside documentation through a digital mobile application for healthcare professionals. By exploring the current workflow, identifying areas for improvement, incorporating user feedback, and evaluating usage, this paper aims to evaluate the mobile application's usability, and efficiency in supporting healthcare professionals toward improved documentation practices, and the cultural transformation impacted by healthcare IT. We focus on analyzing the ability of a digital mobile application to address the desktop documentation challenges and derive design guidelines for our design and development process for clinical documentation. Thus, we arrived at two research questions: (i) *What are the benefits and drawbacks of using a desktop computer for clinical documentation in comparison to a digital mobile application?* and (ii) *How can a digital mobile application for healthcare professionals be designed and developed to improve patient safety and increase efficiency?*

Literature Review

Information infrastructure in healthcare often consists of large heavyweight IT constellations that are becoming increasingly complex and rigid, requiring extensive time and effort to facilitate change and to meet innovation needs (Ellingsen et al., 2024; Severinsen et al., 2022). The integration of digital health technology (hereinafter DHTs) has become more prevalent in the healthcare industry, revolutionizing the way patient care is delivered (Mahajan et al., 2021; Oddsson et al., 2022). DHTs refer to the use of digital platforms, connected sensors, and mobile applications to enhance patient lives and work within healthcare settings (Sharma et al., 2018). Increasingly, lightweight IT applications, complementary to the existing heavyweight IT, are entering the e-health field. These innovative and agile applications support immediate user needs and work processes, with simple applications like apps (Bygstad, 2017). With the digital transformation of DHTs and lightweight IT, healthcare professionals are presented with new opportunities to streamline workflows, enhance patient safety, and improve overall efficiency within clinical settings (Rosenlund et al., 2023). However, with these developments come unique challenges and considerations concerning the usability, functionality, and integration of lightweight IT with existing healthcare practices (Yeung et al., 2023). If the benefits of DHTs are to be realized, there are good reasons to address the usability challenges identified by healthcare professionals (Lloyd et al., 2024). DHTs, which are used to enhance the work of healthcare professionals, can also be targeted toward alleviating the cognitive load of memorizing in fast-paced environments (Islind et al., 2019). Those types of DHTs have proven revolutionary in recent years, to enhance record keeping (Ellingsen et al., 2024). While many studies have focused on the impact of the electronic health record (EHR) on healthcare work in general, there are limited studies that focus on

novel additions to enhance the user experience and usability of the EHR (Mörke et al., 2024). Moreover, there is a gap in the literature concerning the feasibility and user experience to evaluate how lightweight IT built as extensions to the legacy systems of EHR, impacts the work of healthcare professionals. When it comes to the work of healthcare professionals, they encounter multiple challenges in their daily tasks, as their work environment is unique and paved with responsibilities. The work environment for nurses and physicians is often described as fast-paced and unpredictable, with them experiencing a particularly heavy cognitive workload. However, bearing the responsibilities of patient care is less taxing with the use of DHTs (Ellingsen et al., 2024). Documentation consumes a significant amount of time for healthcare professionals, detracting from direct patient care (Momenipour and Pennathur, 2019). DHTs that enable bedside, or point-of-care documentation have been shown to reduce documentation time and increase efficiency compared to central stationary desktop documentation (Poissant et al., 2005). Similarly, the use of checklists has improved compliance with guidelines in various clinical settings which positively impacts healthcare settings in general (Boyd et al., 2017).

Prior Works

Patient safety is now inextricably linked to digital transformation. Scanning and tracking technologies have demonstrated measurable safety benefits (Flott et al., 2021). Implementing scanning and tracking protocols consistently across several National Health Services in England hospitals showed a reduction in patient identification errors and never events, where one pharmacy department in the pilot found the technologies reduced error rates by up to 76% (Flott et al., 2021). Furthermore, in the UK, scanning technologies proved beneficial in terms of improving time released for patient care equivalent to 16 nurses per organization as well as improved operational costs with £2.75m efficiency savings per organization annually (Flott et al., 2021). Scanning patients and completing security checks can contribute reliable and stable data for patient status. Accurate documentation also serves as a legal record in case of disputes or malpractice claims and can protect healthcare professionals and the healthcare facility by providing evidence of the care provided (Sharifi et al., 2021). Entering data retroactively gives rise to the potential problem of memory bias. A digital solution can potentially increase compliance and counteract memory bias. The adoption of mobile applications for clinical photo and wound documentation has resulted in benefits such as saving time, enhanced patient safety and quality of care, improved data security, and better accessibility (Jacob et al., 2020). The ability to take pictures has changed how healthcare professionals describe a clinical condition and track the progression of a patient's trajectory over time (Reinders et al., 2023). The benefits and functions of photo documentation through mobile applications can extend to almost any specialty within healthcare e.g., documenting the progression of wound healing (Harting et al., 2015). However, using smartphones for this purpose can raise privacy issues as it can entail the risk of unauthorized access and disclosure of sensitive patient information (Perwej et al., 2022). To address these concerns, studies have been conducted on mobile applications that securely capture and transfer clinical or medical images to the EHR, therefore complying with privacy laws (Wyatt et al., 2020). Wyatt et al., 2020 also evaluated patients' attitudes toward photography using a secure mobile application, indicating favorable attitudes among patients.

Methods

This paper rests on an action design research project (Sein et al., 2011) to design and develop a digital mobile application for healthcare professionals (see Figure 1). It focuses on addressing real-world problems through an iterative process that engages both researchers and practitioners, while also contributing theoretical insights gained from solving these issues (Sein et al., 2011). The app was co-designed, involving healthcare professionals (those who will be using the app), heads of departments, and the digital development team in the design process. The motivation behind this was to ensure that the respective needs of the different user groups were met (Islind et al., 2019). For our action design research project, we utilized several types of data sources. We used two questionnaires, a survey, and application analytics to collect quantitative data and complemented that with the qualitative data that we gained from the semi-structured interviews. We went through multiple iterations utilizing these mixed-method data-gathering activities (Byrne and Humble, 2007). First, we developed an alpha version of a mobile application that was tested

with one department at the hospital. Second, based on the learnings of the first round we developed a beta version of the mobile app that we evaluated in two additional departments. We decided to focus our study on departments where the protocol for documentation included either security checks or photo documentation. We measured the usage of the new workflow for three months after adoption and compared that to the documentation three months before introducing the new workflow. Finally, that version was turned into a digital artifact.

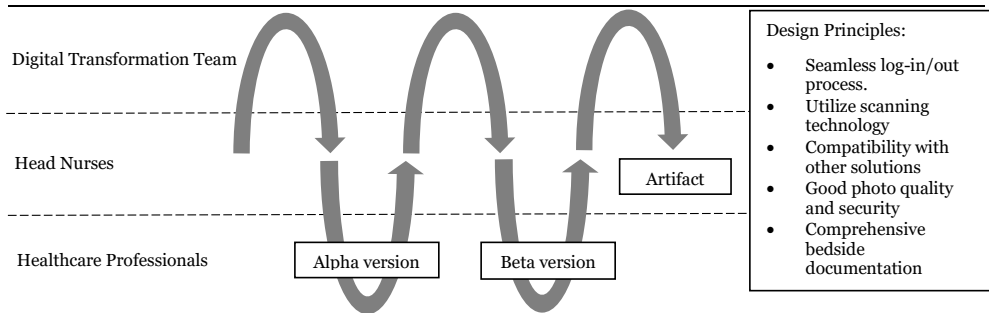


Figure 1. Action Design Research approach

Alpha version

This stage is a problem formulation stage that identifies and conceptualizes a research opportunity based on existing theories and technologies (Sein et al., 2011). We started this practice-inspired research by mapping the needs of our three primary user groups: i) healthcare professionals, ii) head nurses, and iii) the digital transformation team. In total, six participants took part in the semi-structured interview. Based on the results of this phase, we developed the alpha version of the mobile application. The initial design was tested with the head nurse and healthcare professionals from a single department. They were asked to complete a list of tasks and do a think-aloud test using the alpha version. The healthcare professionals were also asked to use the alpha version in their daily work for three months. From the feedback, we created an overview of the issues and prioritized them according to their severity.

Beta version

We tested the beta version of a mobile app with two additional hospital departments in two phases. In phase one, the head of nursing gathered healthcare professionals to test the app and be interviewed. Participants were selected based on availability and informed they could withdraw at any time - none did. We collected responses from 21 participants (age 21-58, mean 38), including eleven nurses, seven nurse associates, one doctor, one medical student, and one specialized employee. They performed user testing cases, completed demographic and background surveys, and answered the System Usability Scale (SUS) and AttrakDiff questionnaires. Test cases included the following tasks: (i) take a photo, write a description, and send it to the patient's records, (ii) complete a security checklist at the start of a shift, (iii) complete a regular security checklist, and (iv) log out of the application. In phase two, we evaluated app usage by comparing EHR desktop logs three months before and after implementation. Nurse associates performed security checks at the start of shifts and every two hours, using barcode scanning or SSN input to verify patients before submitting checklists. We compared completion times, and the number of checks performed daily. For photo documentation, we analyzed three nurses' logs before and after app access. Nurses scanned a patient's barcode or entered an SSN, took a photo, added comments, and uploaded them to EHRs, eliminating local storage and improving security. We measured time savings and increased photo documentation.

Artifact

Three months after the implementation of the mobile application we visited the departments again to gather feedback about their experience with the beta version. We formalized the learnings from the building of the IT artifact, interventions in the organization, and evaluation of the results from the beta version. To conclude the study, we conducted semi-structured interviews with the healthcare professionals who used the mobile app. These outcomes can be characterized as design principles that contributed to the design of a mobile bedside documentation application.

Results

We will now present the findings from user tests with the alpha version, the beta version, and the artifact.

Alpha version

Doctors, nurses, and nurse associates across the hospital frequently raised the pain point of not having an easy and secure way to transfer photos to the EHRs. After meeting with four nurses in the roles of heads of departments another point emerged with the security checks that were performed every two hours for inpatients. This was a task that was performed 24 hours a day and the nurse associates performing the tasks would either write the results on paper or simply just mark a checklist as “complete” on a desktop computer without going through all the steps of the checklist. We used this information to formulate the problem in three steps: (i) to structure the problem, (ii) to identify solution possibilities, and (iii) to guide the design. The digital transformation team developed a mobile application that was then tested for three months in an inpatient department at the hospital. Multiple errors were identified with the mobile application which led to rewriting most of the code of the interface. From a design perspective, the most important point that emerged from the testing was that the log-in method needed to be changed. In the alpha version, we relied on log-in through the national electronic ID card which meant that healthcare professionals needed their personal phone to authenticate the log-in. This was an issue because some healthcare professionals had their phones stored in lockers during shifts.

Beta version

All participants successfully carried out user tasks, indicating an intuitive interface, that could encourage usage and therefore patient safety. The standardized usability questionnaire, the System Usability Scale (SUS), revealed an average score of 72.7 (SD 23.4) for the application, indicating good usability with a grade of B. For context, the median SUS score is 68, and a score of 75 reflects superior performance, surpassing 73% of other products (Sauro and Lewis, 2016). The user experience questionnaire, AttrakDiff, showed scores ranging from 1.1 to 1.4 on all subscales (Figure 2). This questionnaire assesses users' perceptions across four areas: Pragmatic Quality (PQ) evaluates usability (mean = 1.35), suggesting room for improvement; Hedonic Quality – Identity (HQ-I) assesses alignment with user identity (mean = 1.16), indicating potential for improvement; and Attractiveness (ATT), which evaluates overall appeal (mean = 1.41), suggesting a positive impression of the product; Hedonic Quality - Stimulation (HQ-S) measures engagement (mean = 1.15), which is a less critical focus. Overall, the results indicate that while users find the application moderately usable and attractive, there are areas that could benefit from enhancement.

The Head of the Department at the inpatient department encouraged the use of the mobile application during the implementation period. After three months, 26 out of 33 (79%) healthcare professionals used the application. On average, 2.27 (SD 1.1) out of 5 nurse associates logged in daily on weekdays, compared to 1.27 (SD 1.3) on weekends ($p = 0.0036$), possibly due to replacement staff not receiving workflow information. No significant difference was observed in the number of security checks documented or time spent completing them. However, the timeliness of security checks improved with the mobile application. The average deviation from the two-hour interval was 29 min. 46 sec. (SD 19 min. 45 sec.) using the desktop process, compared to 27 min. 33 sec. (SD 19 min. 52 sec.) with the mobile app – a significant 7.5% improvement ($p = 0.0046$). Results are shown in Figure 3, with statistical tests summarized in Table 1.

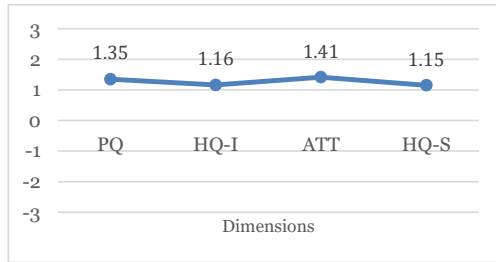


Figure 2. Results from the AttrakDiff questionnaire.

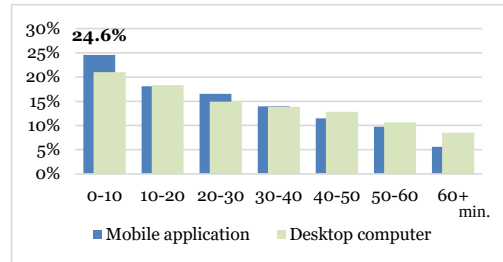


Figure 3. Timeliness of security checks.

All three nurses at the outpatient reception fully adopted the mobile application for photo documentation. The old process of uploading photos took an average of 2 minutes (SD 1 min. 46 sec.), while the mobile application reduced this time to 10.8 seconds (SD 4.4 sec.), a significant improvement ($p = 0.0066$). The average number of patients photographed per shift increased by 39%, from 2.9 (SD 1.75) before implementation to 4.0 (SD 1.83) after ($p = 0.0021$). The average number of photos per patient slightly decreased from 2.0 (SD 1.71) to 1.8 (SD 0.62), though this was not statistically significant. Results are summarized in Table 1.

Inpatient dep. measuring security checks				Outpatient dep. measuring photo documentation			
	Desktop	Mobile	p-value		Desktop	Mobile	p-value
Time performing a security check	64.6 sec.	62.5 sec.	$p = 0.3589$	Time taking a photo	120 sec.	10.8 sec.	$p = 0.0066$
	15.5 sec. SD	10.39 sec. SD			106 sec. SD	4.4 sec. SD	
	N = 30 obs.	N = 30 obs.			N = 30 obs.	N = 30 obs.	
Weekly security checks per nurse associate	87.1	83.3	$p = 0.3395$	Patient photographed per dayshift	2.9 patients	4.0 patients	$p = 0.0021$
	39.6 SD	39.7 SD			1.75 SD	1.83 SD	
	N = 13 weeks	N = 13 weeks			N = 51 days	N = 51 days	
Proximal time from an event	29:46.0	27:33.0	$p = 0.0046$	Photos per patient (pt)	2.0 photos	1.8 photos	$p = 0.2000$
	19:45.0 SD	19:52.0 SD			1.71 photos SD	0.62 photos SD	
	N = 11723	N = 574			N = 109 pt	N = 205 pt	

Table 1. Improvements in efficiency for inpatient and outpatient workflows

From the semi-structured interviews of the beta version we received (i) ideas on additional features such as accessing patient guidelines, comparing photos over time, receiving notifications on security checks, and the option of documenting outcomes of various clinical bedside exams, (ii) ideas of how we could develop the web application that receives information documented in the mobile app so that the web app and mobile app complemented each other better, (iii) feedback on photo quality and additional photography features such as zoom and flash capabilities, (iv) pointers on the need for additional language options, and (v) concerns about using mobile phones for professional purposes, mentioning professionalism and patient perception as key considerations.

Artifact

We interviewed the participants again three months after introducing the mobile application into the workflow. Healthcare professionals mentioned that (i) the utility of the mobile app was limited, but in general they were pleased with the features that were already in the app, (ii) the app would benefit them more if it was implemented across all departments, (iii) they were more likely to take photographs when using the novel feature, as it supported the work well, (iv) the need to rethink the method of scanning wristbands during night shifts, and (v) the advantage of the patient safety factor scanning patients wristbands. Some generational aspects were identified by one of the nurse associates, to highlight that the mobile application would gain traction to a larger extent in the coming years: *“Some staff are still using the desktop computer. All the new staff immediately started using the app. The old ones are still typing on the*

computer. The new and young people immediately took to the app.” During the final testing phase, an adverse event occurred where photos taken of a patient were lost in the transition to the EHRs. From that experience, we learned that we needed to design an alternative route for sending photos in cases where the app did not perform for reasons such as poor internet connection, downtime of servers, or other reasons. The alternative route also needed to be very visible to the user. These key themes provide valuable insights into users' preferences, concerns, and suggestions for improving the application's functionality and usability can potentially enable healthcare professionals to deliver safer and more effective healthcare. See examples from the alternative route for photos in Figure 4 below. Addressing these themes can help enhance users' satisfaction and optimize the effectiveness of healthcare professional's workflow and patient safety.

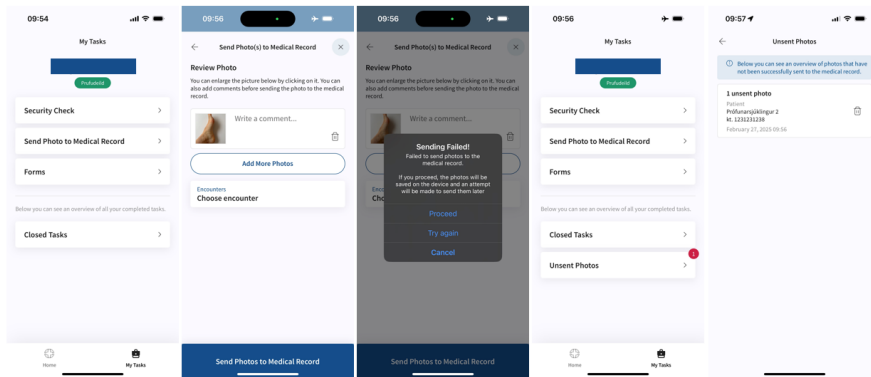


Figure 4. Examples of the alternative route for photos

Discussion

In this paper, we address two areas of interest. Firstly, we focus on the main benefits and drawbacks of using desktop computers for clinical documentation such as security checks and photo documentation. The findings from that part outline our requirements. Secondly, we use those requirements to design and develop a digital mobile application for healthcare professionals to support patient safety by counteracting memory bias, increasing efficiency, and patient data security. The results of the feasibility analysis included a good usability score close to 73, and positive user experience scores ranging from 1.1 to 1.4 on all subscale areas. Most user test cases were completed with ease indicating that the application has an intuitive interface well-suited for the hospital work environment. The new workflow with the mobile application significantly improved the documentation of security checks and photo documentation. Security checks were documented closer to the actual time of examination, and the photo documentation features saved healthcare professionals significant time and allowed for a more secure transfer of photos to EHRs. The interviews with the healthcare professionals yielded valuable insights into the development of new features and their experience of using the application for the first three months.

As DHTs and lightweight IT continue to digitally transform the healthcare system, engaging healthcare professionals in the design and development process is imperative. Their first-hand experience and deep understanding of both the work environment and patient's needs are vital in ensuring the successful development and adoption of DHTs (Troncoso and Breads, 2021). Healthcare professionals have found these tools to integrate well into their work routines, improving task efficiency while also enhancing and securing the quality of care and patient safety. Moreover, healthcare professionals generally hold a positive view of DHTs (Mohsam, 2024). Therefore, it is important to include them systematically during the design of the DHTs that will impact their work. In organizations with complex work practices, such as hospitals, it is generally recognized that only the users themselves know the practice sufficiently well to be able to assess the suitability of the system (Malm-Nicolaisen et al., 2024). This study focused on user engagement and co-design, which aligns with broader trends in digital health solution development. Actively involving

healthcare professionals in design and testing, allows organizations to ensure that the technology meets end-users' needs and integrates into existing workflows (Papoutsis et al., 2021; Troncoso and Breads, 2021). Particularly emphasizing its potential in enhancing patient safety and streamlining clinical workflows. As healthcare professionals navigate daily work challenges, including heavy cognitive workloads and time-consuming documentation tasks, integrating innovative solutions becomes imperative. We also highlight the critical role of user engagement in designing and implementing DHTs, recognizing the valuable insight and perspectives that healthcare professionals bring to the development process. Using healthcare professionals' firsthand experience and understanding of both the work environment and patient needs, alongside robust user testing methodologies, healthcare organizations can optimize the usability, effectiveness, and acceptance of digital health solutions, thereby improving patient safety. With further digital transformation and as the DHT industry evolves, collaboration between technology designers and developers, healthcare professionals, and patients will be essential in driving innovation and improving healthcare delivery for all.

Future improvements that support usability, efficiency, and patient safety for bedside documentation include implementing new features suggested by healthcare professionals, such as notifications for safety check-ins, clinical evaluation papers, and enhanced capabilities for medical procedures such as tube feeding and draining. Further improvements in the log-in process by allowing healthcare professionals to simply sign into mobile phones with the touch of their ID card. Additionally, addressing the concerns regarding photo quality, storage, and display in patient records could improve usability and clinical documentation. Also, mitigating the perception of looking unprofessional when using a smartphone to gather or register medical information could be managed by placing a visible hospital logo on the work phones. Prioritizing co-design and iterative development cycles can allow the application to continue to evolve in response to changing user preferences and technology. The insights gained from this study can inform the ongoing development of DHTs within healthcare. Comparing our findings to existing literature, we can identify common challenges, best practices, and opportunities for innovation. For instance, the integration of bedside documentation and checklists has been shown to improve efficiency and patient safety (Boyd et al. 2017; Poissant et al. 2005). Based on our findings in this paper, we summarize our main contribution into five design guidelines for designing and developing a mobile application for bedside documentation:

1. **Seamless and secure log-in/out process:** The log-in process needs to be simple and secure so that healthcare professionals do not waste precious time. The log-out process or an automated log-out process ensures that clinical documentation is always done in the right name.
2. **Utilize scanning technology:** The scanning process improves the usability of the application as well as supports accurate documentation, considering traceability and convenience.
3. **Compatibility with other solutions:** The mobile application needs to be compatible with other systems in use at the hospital such as the electronic whiteboards and web applications.
4. **Photo quality and security:** The photo quality needs to have sufficient resolution to capture the details of wounds. There was great emphasis on security regarding photos and concerns about how to proceed when it was not possible to send a picture at a certain point in time.
5. **Comprehensive bedside documentation:** It is important that healthcare professionals can complete most of the tasks that they do during bedside visits. If the app only covers a fraction of the most common procedures, then the value of the application is less in the eyes of healthcare professionals.

Conclusion

In this paper, we show that bedside documentation through desktop stationary computers has limitations, and a mobile application, as an extension to the EHRs, can improve the timeliness of security checks, increase photo documentation, and thereby patient safety. From our findings, we derive five guidelines for the design of digital health technologies in general and bedside documentation in particular. The five guidelines are the following: (i) seamless and secure log-in/out process, (ii) utilizing scanning technology, (iii) compatibility with other solutions, (iv) photo quality and security, and (v) comprehensive bedside documentation. Moreover, we learned that transparency is important when errors occur, and designing alternative routes might be necessary for healthcare professionals to carry on with their work. This study shows the need for careful design of mobile applications when realizing those in complex digital health

contexts. Incorporating mobile applications into the work of healthcare professionals to perform bedside documentation significantly improves documentation, outlining better and more reliable data over time.

Acknowledgements

We thank the healthcare professionals who provided their feedback on using the mobile application. We also thank Jón Árne Bragason, Þorri Már Sigurbórsson, and the app development team for their contributions.

REFERENCES

- Asmirajanti, M., Hamid, A. Y. S., & Hariyati, R. T. S. (2019). Nursing care activities based on documentation. *BMC nursing*, 18, 1-5.
- Boyd, J. M., Wu, G., & Stelfox, H. T. (2017). The impact of checklists on inpatient safety outcomes: a systematic review of randomized controlled trials. *Journal of hospital medicine*, 12(8), 675-682.
- Bygstad, B. (2017). Generative innovation: a comparison of lightweight and heavyweight IT. *Journal of information technology*, 32(2), 180-193.
- Byrne, J., & Humble, Á. M. (2007). An introduction to mixed method research. *Atlantic research centre for family-work issues*, 1, 1-4.
- Ellingsen, G., Grisot, M., Hertzum, M., & Islind, A. S. (2024). Implementing Electronic Health Records—Objectives, Obstacles, Outcomes. European Conference on Computer-Supported Cooperative Work.
- Flott, K., Maguire, J., & Phillips, N. (2021). Digital safety: the next frontier for patient safety. *Future Healthcare Journal*, 8(3), e598-e601.
- Harting, M., DeWees, J., Vela, K., & Khirallah, R. (2015). Medical photography: current technology, evolving issues and legal perspectives. *International journal of clinical practice*, 69(4), 401-409.
- Islind, A. S., Lindroth, T., Lundin, J., & Steineck, G. (2019). Shift in translations: Data work with patient-generated health data in clinical practice. *Health informatics journal*, 25(3), 577-586.
- Jacob, C., Sanchez-Vazquez, A., & Ivory, C. (2020). Factors impacting clinicians' adoption of a clinical photo documentation app and its implications for clinical workflows and quality of care: qualitative case study. *JMIR mHealth and uHealth*, 8(9), e20203.
- Lloyd, S., Long, K., Probst, Y., Di Donato, J., Oshni Alvandi, A., Roach, J., & Bain, C. (2024). Medical and nursing clinician perspectives on the usability of the hospital electronic medical record: A qualitative analysis. *Health Information Management Journal*, 53(3), 189-197.
- Mahajan, S., Lu, Y., Spatz, E. S., Nasir, K., & Krumholz, H. M. (2021). Trends and predictors of use of digital health technology in the United States. *The American journal of medicine*, 134(1), 129-134.
- Malm-Nicolaisen, K., Ellingsen, G., Hertzum, M., Silsand, L., & Severinsen, G. H. (2024). Evolution of Information Infrastructures in Healthcare as Convergence of Digital Trajectories. *Computer Supported Cooperative Work (CSCW)*, 1-28.
- McCarthy, B., Fitzgerald, S., O'Shea, M., Condon, C., Hartnett-Collins, G., Clancy, M., ... & Savage, E. (2019). Electronic nursing documentation interventions to promote or improve patient safety and quality care: A systematic review. *Journal of nursing management*, 27(3), 491-501.
- Mohsam, F. (2024). An Analysis of nurses lived experience with digital health technologies in practice. *Journal of Health Informatics in Africa*, 11(1), 51-63.
- Momenipour, A., & Pennathur, P. R. (2019). Balancing documentation and direct patient care activities: A study of a mature electronic health record system. *International journal of industrial ergonomics*, 72, 338-346.

- Mörike, F., Spiehl, H. L., & Feufel, M. A. (2024). Workarounds in the shadow system: An ethnographic study of requirements for documentation and cooperation in a clinical advisory center. *Human factors*, 66(3), 636-646.
- Oddsson, S. J., Gunnarsdottir, T., Jóhannsdóttir, L. G., Amundadóttir, M. L., Frimannsdóttir, A., Molander, P., Ylanne, A. K., Islind, A. S., Óskarsdóttir, M. & Thorgeirsson, T. (2023). A new digital health program for patients with inflammatory bowel disease: preliminary program evaluation. *JMIR Formative Research*, 7(1), e39331.
- Papoutsis, C., Wherton, J., Shaw, S., Morrison, C., & Greenhalgh, T. (2021). Putting the social back into sociotechnical: Case studies of co-design in digital health. *Journal of the American Medical Informatics Association*, 28(2), 284-293.
- Perwej, Y., Akhtar, N., Kulshrestha, N., & Mishra, P. (2022). A methodical analysis of medical internet of things (MIoT) security and privacy in current and future trends. *Journal of Emerging Technologies and Innovative Research*, 9(1), d346-d371.
- Pine, K. H., Landon, L. A., Bossen, C., & VanGelder, M. E. (2023). Innovations in clinical documentation integrity practice: Continual adaptation in a data-intensive healthcare organisation. *Health Information Management Journal*, 52(2), 119-124.
- Poissant, L., Pereira, J., Tamblyn, R., & Kawasumi, Y. (2005). The impact of electronic health records on time efficiency of physicians and nurses: a systematic review. *Journal of the American Medical Informatics Association*, 12(5), 505-516.
- Reinders, P., Augustin, M., Kirsten, N., Fleyder, A., & Otten, M. (2023). Digital health interventions in dermatology—Mapping technology and study parameters of systematically identified publications. *Journal of the European Academy of Dermatology and Venereology*, 37(12), 2440-2449.
- Rosenlund, M., Kinnunen, U. M., & Saranto, K. (2023). The use of digital health services among patients and citizens living at home: scoping review. *Journal of Medical Internet Research*, 25, e44711.
- Sauro, J., & Lewis, J. R. (2016). *Quantifying the user experience: Practical statistics for user research*. Morgan Kaufmann.
- Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. *MIS quarterly*, 37-56.
- Severinsen, G. H., Silsand, L., Malm Nicolaisen, K., Pedersen, R., & Ellingsen, G. (2022). Introducing Lightweight IT—A Way to Build Flexibility for Healthcare Organizations? In *Challenges of Trustable AI and Added-Value on Health* (pp. 199-203). IOS Press.
- Sharifi, S., Zahiri, M., Dargahi, H., & Faraji-Khiavi, F. (2021). Medical record documentation quality in the hospital accreditation. *Journal of education and health promotion*, 10(1), 76.
- Sharma, A., Harrington, R. A., McClellan, M. B., Turakhia, M. P., Eapen, Z. J., Steinhubl, S., ... & Peterson, E. D. (2018). Using digital health technology to better generate evidence and deliver evidence-based care. *Journal of the American College of Cardiology*, 71(23), 2680-2690.
- Troncoso, E. L., & Breads, J. (2021). Best of both worlds: digital health and nursing together for healthier communities. *International nursing review*, 68(4), 504-511.
- Wyatt, K. D., Finley, A., Uribe, R., Pallagi, P., Willaert, B., Ommen, S., Yiannias, J., & Hellmich, T. (2020). Patients' experiences and attitudes of using a secure mobile phone app for medical photography: qualitative survey study. *Journal of medical Internet research*, 22(5), e14412.
- Yeung, A. W. K., Torkamani, A., Butte, A. J., Glicksberg, B. S., Schuller, B., Rodriguez, B., Ting, D. S., Bates, D., Schaden, E., & Peng, H. (2023). The promise of digital healthcare technologies. *Frontiers in Public Health*, 11, 1196596.

Appendix C

Improved Healthcare Delivery Process for Patients with Atrial Fibrillation: Design Principles and a Novel Digital Health Platform

Improved Healthcare Delivery Process for Patients with Atrial Fibrillation: Design Principles and a Novel Digital Health Platform

Lilja Guðrún Jóhannsdóttir, PhD student, Department of Computer Science, Reykjavík University
Helga Ýr Erlingsdóttir, Nurse Specialist in Cardiology, Department of Cardiology, Landspítali Hospital
Sigfús Örvar Gizurarson, Cardiologist PhD, Department of Cardiology, Landspítali Hospital
Kristján Guðmundsson, Cardiologist, Department of Cardiology, Landspítali Hospital
Herdís Kristjánsdóttir, Nurse, Department of Computer Science, Reykjavík University
Björn Jónsson, Department of Digital Progress, Landspítali Hospital
María Óskarsdóttir, PhD, School of Mathematical Science, University of Southampton and Department of Computer Science, Reykjavík University
Anna Sigríður Islind, PhD, Department of Computer Science, Reykjavík University

Abstract

Atrial fibrillation (AF) is the most common sustained arrhythmia in clinical practice and is associated with an increased risk of stroke, heart failure, dementia, and death. Its clinical consequences are largely the result of risk factors that can be modified by lifestyle changes. In this paper, we design and develop a patient journey for patients receiving treatment for AF to improve patient safety and healthcare delivery processes. This is an empirical study based on an action design research project where the main contributions consist of five design principles: (i) detailed request for surgery, (ii) visualization of patient trajectory, (iii) prioritization of patient waiting list based on real-time data, (iv) uphold equality and inclusion throughout patient journey, and (v) quick access and visualization of quality indicators. Furthermore, we propose a digital health platform design for patients with AF that follows these design principles.

Introduction

Atrial fibrillation (AF) is the most common heart arrhythmia, and if left untreated, it can lead to serious health complications, including heart failure, cardiomyopathy, stroke, dementia, depression, and a diminished quality of life (Virani et al., 2021; Hindricks et al., 2021). In Europe, AF places a significant financial strain on healthcare systems, underscoring the urgent need for strategic planning to meet growing demands (Ringborg et al., 2008). Many of the risks associated with AF can be managed through lifestyle changes (Elliot et al., 2023), making prevention and proactive care essential. As [country's] population continues to age, the healthcare system must prepare for an increasing number of AF patients who require ongoing medical support, complex medication regimens, and frequent monitoring (Stefansdottir et al., 2011). This is where digital health technology can play a transformative role. A mobile application designed and developed for individuals with AF could provide real-time monitoring, prioritize healthcare visits based on symptom severity, and support patients in making crucial lifestyle adjustments. Key focus areas would include exercise, weight management, sleep quality, blood pressure control, reducing alcohol and tobacco use, and adopting a heart-healthy diet. To ensure optimal care, the 2020 ESC guidelines recommend a

comprehensive treatment approach that not only manages symptoms through rate and rhythm control but also targets underlying lifestyle-related risk factors (Hindricks et al., 2021). A well-designed app could bridge the gap between scientific research, expert recommendations, and patient care, offering tailored guidance, reminders for prescribed treatments, and remote monitoring in a user-friendly format. The integration of digital health technology into AF management could grant patients greater control over their health trajectory while reducing the burden on healthcare providers.

Efficient resource allocation is crucial to maintaining high-quality care, especially in healthcare systems that are under strain due to a shortage of healthcare workers. The [hospital name blinded] is the main healthcare center in [country] and the only hospital in [city] with inpatient, outpatient, and emergency care services. In addition, it is the only facility where radiofrequency ablation, cryoablation, or pulsed field ablation for AF is performed. The Department of Cardiology performs around 350-400 ablations every year. Around 60% of these surgeries are for patients with AF. It is estimated that these surgeries will increase by 10% every year, mainly because of AF. At the National Hospital, two cardiologist specialists perform this procedure in the position of 150%. These two specialists also assess all requests for this procedure and oversee all patients' rehabilitation and recovery after surgery with the assistance of specialist nurses. A mobile app remotely monitors AF patients by categorizing their symptoms into stable (green), mild (yellow), or severe (red), ensuring that those in urgent need receive priority care. This has the potential to optimize healthcare resources while improving patient outcomes, reducing emergency visits, and enhancing quality of life. Implementing this solution at the National Hospital's outpatient Department of Cardiology could pave the way for broader adoption across [country's] healthcare system. In addition to symptom tracking, an app offers educational resources, lifestyle guidance, treatment reminders, and motivation from healthcare professionals. Patients with AF in [country] have inadequate knowledge of their conditions and half of them have insufficient health literacy (Erlingsdóttir et al., 2023). This is similar to what is reported in other counties (Sørensen et al., 2015). AF knowledge may be improved using a mobile application where patients are actively involved in the care and health literacy is considered in the provided patient education. Therefore, a mobile app could potentially lead to better disease management and more efficient use of healthcare resources.

This paper presents an action design research project with the aim of designing a patient journey through a digital health platform for patients with AF while improving patient safety and healthcare delivery processes. The emphasis of the patient journey is: (i) to collect quality data when an ablation request is sent to the Department of Cardiology at the National Hospital, (ii) to collect quality data throughout the patient journey and (iii) to utilize remote monitoring for further data collection and patient engagement. By exploring the current workflow, identifying areas for improvement, incorporating user feedback, and evaluating usage, this paper aims to evaluate the digital health platform's usability and efficiency in supporting healthcare professionals. We derive design principles for our design and development process for managing patients with AF and focus on analyzing the ability of a digital health platform to address the current challenges. Thus, we arrived at the research question: *How can a digital health platform be designed and developed to improve patient safety and increase efficiency for patients with AF?* The project involves implementing remote monitoring and remote support in the AF outpatient Department of Cardiology. The digital health platform also provides advice on a healthy lifestyle, which improves patients' health behavior and

can reduce severe symptoms of the disease. Remote monitoring can prioritize visits and reduce the number of urgent events, including emergency room visits.

Methods

This paper rests on an action design research project (Sein et al., 2011) with the aim of designing and developing a digital health platform for healthcare professionals (see Figure 1). The digital health platform was co-designed, involving healthcare professionals (those who will be using the platform), clinical experts, and the digital development team (researchers) in the design process. The motivation behind this was to ensure that the respective needs of the different user groups were met (Islind et al., 2019). For our action design research project, we utilized several types of data sources. We used two questionnaires and application analytics to collect quantitative data and complemented that with the qualitative data that we gained from semi-structured interviews. We went through multiple iterations utilizing these mixed-method data-gathering activities (Byrne and Humble, 2007). First, we developed an alpha version of a patient journey through the digital health platform. Second, based on the learnings of the first round we developed a beta version of the digital health platform that we evaluated with the Department of Cardiology. Finally, based on the feedback of the healthcare professionals we formalized design principles that should guide the design goals of the final artifact.

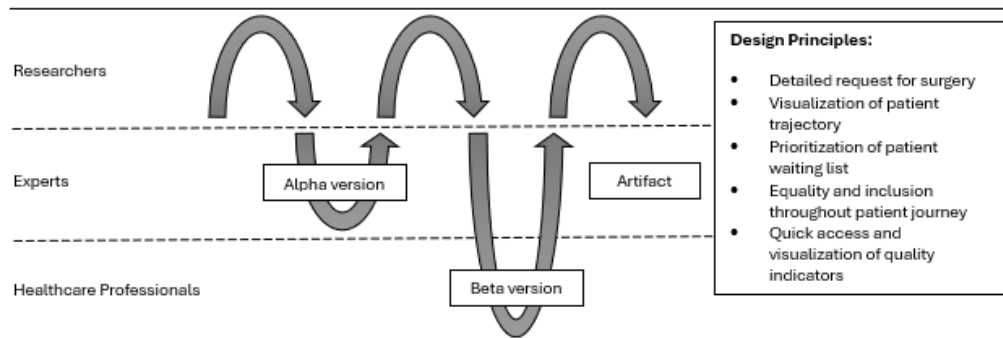


Figure 1. Action Design Research approach

Alpha version

We had an expert workshop in December 2023 where two doctors and two digital product managers mapped out the pain points in the current process. The discussion was on the gains and opportunities of digitally transforming the processes for patients with AF and how a mobile application could be utilized. The result of the workshop was an alpha prototype in the form of a patient journey. Some of the features utilized in the patient journey already existed and only needed

to be applied to the AF patient at the CD, such as the digital surgery requests and the mobile application for patients. Other features, such as a patient group rule engine, needed to be developed to meet the needs of the AF patient's journey.

Beta version

The request from the experts was that throughout the patient journey, the digital health platform would (i) collect quality data when an ablation request is sent to the Department of Cardiology at the National Hospital, (ii) collect quality data throughout the patient journey, and (iii) utilize remote monitoring for further data collection and patient engagement. First, we created a custom digital surgery request for ablations that made it mandatory for cardiologists to fill in relevant information. Second, we created a digital registration form that could be used to collect information when patients were prepared for surgery, during surgery, and in the follow-up after surgery. Third, we adjusted an already available mobile application for patients to meet the needs of healthcare professionals managing AF patients. This required building a group-based rule engine that would send automatic messages and notifications to patients while they were on the waiting list and during follow-up after the surgery. This required several development sprints in the year 2024. We had ten healthcare professionals participate in the testing and evaluation of this beta version, which was based on the patient journey developed as an alpha version. The beta version was built within the web application of the National Hospital's digital health platform where the features include digital surgery requests, registration forms for data collection, and patient groups that are the basis for patient management and the rule engine. The data collection of the ten participants was based on the two standard questionnaires, System Usability Scale (SUS) and AttrakDiff, as well as semi-structured interviews.

Artifact

Based on learning from the building, interventions, and evaluation of the beta version we formalized design principles that should guide the design goals of the final artifacts. Implementation continued and quality indicators were considered based on the data that was now being collected from the patients with AF. These outcomes can be characterized as design principles that contributed to the design goals of the final artifact.

Results

Alpha version – Patient Journey

In this phase, we conducted an expert workshop with two cardiologist specialists and two digital product managers to create a patient journey for patients with AF. The results of that workshop were a visualization of the patient journey, where we identified the missing elements as well as the main emphasis. The needs of the experts in cardiology can be categorized into three main points (i) digital surgery requests, (ii) building an AF registry, and (iii) remote monitoring and patient engagement through a mobile application.

Digital surgery requests: The implementation of a digital surgery request system for the ablations was expected to improve traceability and reduce paperwork being lost. The standardized request forms had mandatory fields, to ensure better patient selection and pre-surgery preparation. They were also

expected to address inefficiencies in the long waiting list (6 months – 2 years) by utilizing the time for pre-surgery interventions and patient optimization.

Atrial Fibrillation (AF) registry: Develop a certified AF registry with comprehensive demographic and clinical data to enhance quality control and research. Improve data visualization and access to long-term outcome tracking while reducing manual data entry. Ensure compliance with data privacy regulations and streamline integration with hospital databases.

Remote monitoring through a mobile application: Use a mobile app to monitor AF patients on the waiting list, collecting essential health data to optimize pre-surgery preparation. Provide education, symptom tracking, and treatment guidance to improve patient outcomes. Integrate with wearables and sensors (ECG, blood pressure monitors, smart scales, pulse oximeters) for real-time health monitoring. Ensure secure data hosting at the National Hospital and compliance with patient data privacy regulations.

The patient journey starts when a cardiologist sends a digital surgery request to the hospital. The request is processed within 48 hours and if the patients are accepted on a waiting list, they will automatically receive a digital message to the mobile app for patients from the Department of Cardiology and the initial questionnaire. Patients can spend 6 months – 2 years on the waiting list and their health can change drastically during that time. Therefore, patients are monitored remotely every three months with a questionnaire to the patient app. Depending on their response, their symptoms and lifestyle are categorized into stable (green), mild (yellow), or severe (red). If they are marked red a nurse will contact the patient with further advice. The patients undergo medical exams during pre-op preparation and the nurses collect that data using a custom registration form. The nurses also collect further data during the surgery concerning the procedure itself and heart anatomy. The patients are usually discharged the same day and receive a questionnaire in the patient app for a 1-month post-op. Then for 6 months post-op the patients will visit the operating doctor but should complete the 6-month post-op questionnaire before arrival. The final questionnaire is sent to the patients 12 months post-op and if the patients completed the rehabilitation successfully the session with the Department of Cardiology is closed with a report sent to the patient app. The patients receive further monitoring with their responsible cardiologist. The data collection through the patient journey is presented in Figure 2 below.

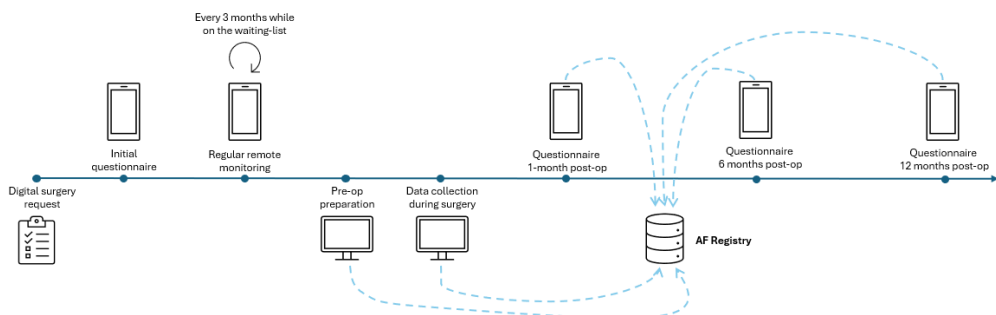


Figure 2. Data collection through the AF patient journey

Beta version – Building, Intervention, and Evaluation

We created a digital surgery request for ablations that made it mandatory for cardiologists to fill in relevant information. However, the request had not been implemented at the Department of Cardiology at the time of the beta version evaluation. We also created a digital registration form that could be used to collect information about patients when prepared for surgery, during surgery, and in the follow-up after surgery. The digital health platform is two-fold, on the one hand, a web application and on the other hand a mobile application (hereinafter called app). The registration form could either be filled out by a healthcare professional in a web application or sent to the patients through the patient app. The nurses started using the registration forms for pre-op and surgery data collection in June 2024. We started sending questionnaires to patients on the waiting list in January 2025 and to post-op patients in March 2025. Healthcare professionals would remotely monitor the responses from the patients through so-called patient groups in the web application for healthcare professionals. We collected user feedback from 10 healthcare professionals in the form of two standard questionnaires (SUS and AttrakDiff) as well as semi-structured interviews.

The standardized usability questionnaire, the SUS, revealed an average score of 65.5 (SD 14.3) for the application, indicating around average usability with a grade of C. For context, the average SUS score is 68, and a score of 75 reflects superior performance, surpassing 73% of other products. The user experience questionnaire, AttrakDiff, showed scores ranging from 0.7 to .94 on all subscales (Figure 3). This questionnaire assesses users' perceptions across four areas: Pragmatic Quality (PQ) evaluates usability (mean = 0.70), suggesting room for improvement; Hedonic Quality – Identity (HQ-I) assesses alignment with user identity (mean = 0.94), Attractiveness (ATT), which evaluates overall appeal (mean = 0.84) indicating potential for improvement; and Hedonic Quality - Stimulation (HQ-S) measures engagement (mean = 0.94) suggesting a positive impression of the product. Overall, the results indicate that while users find the application moderately usable and attractive, there are areas that could benefit from enhancement.

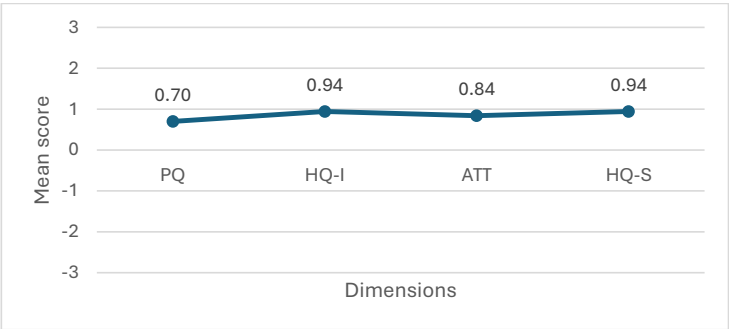


Figure 3. Results from the AttrakDiff questionnaire

From the semi-structured interviews of the beta version we received feedback that could be categorized into the main themes (i) challenges in patient follow-up and communication if flagged red, (ii) the need to send automatic educational material to patients, (iii) need for a better overview of patient trajectory, (iv) missing automation in data processing and displaying of quality indicators,

(v) overall concerns about how to best engage patients to adopt a healthier lifestyle, and (vi) concerns about equal access to care once the digital journey is fully implemented.

Artifact – Design Goals

Based on the feedback from healthcare professionals during the evaluation of the beta version it is evident that changes need to be made to improve both the usability and user experience of the web application. The data collection into the AF Registry has only been running for ten months, and the data will become richer during the continued implementation of the digital health platform. There is a need for data validation, data analytics, and definitions of quality indicators. Healthcare also asked for better instant visualization of data that was collected throughout the digital patient journey. The key themes gathered in the beta version evaluation provide valuable insights into users' preferences, concerns, and suggestions for improving the application's functionality and usability. These outcomes can be characterized as design principles that contribute to the design of the final artifact.

Discussion

In this paper, we address the research question: *How can a digital health platform be designed and developed to improve patient safety and increase efficiency for patients with AF?* We started by mapping out the patient journey where we identified all the places necessary to collect more data from either healthcare professionals or the patients themselves. Collecting and reflecting on quality data is the cornerstone to improve patient safety and increase efficiency for patients. While on the waiting list, the data collection through a digital surgery request is expected to optimize the prioritization of patients into surgery, monitor patients' health trajectories, provide guidance when needed, educate patients about symptoms, and increase health literacy. Managing a diverse surgical waiting list is challenging. Some patients are in good health, while others are critically ill. Yet, referrals sometimes contain just a few lines, far from enough to assess their true condition. It is important to identify those unlikely to benefit from surgery, avoiding unnecessary risks and costs, while prioritizing those in urgent need. Right now, referrals rely on brief doctor's notes, often based on a single visit, with no follow-up for months or even a year, during which a patient's condition can change drastically. Better tracking is key and by monitoring patients over time, it is possible to ensure timely interventions for those who need them while safely delaying procedures for others. That is how real-time data could transform patient care.

Maximizing the chances of a successful outcome after surgery starts long before the procedure itself. The waiting period presents a valuable opportunity to encourage lifestyle changes and optimize treatment, leading to better overall results. Some patients may improve so much that they no longer need ablation, while others will experience significantly better outcomes due to proper preparation. Utilizing technology, continuous monitoring and personalized motivation become more effective than traditional in-person visits alone. With a more inclusive approach, it becomes easier to track progress across all patients, ensuring no one is overlooked. If a patient is not making the expected progress, the app can step in, recommending further tests or treatments to keep them on the right path. This proactive strategy could not only improve individual results but also enhance the overall efficiency of care.

To name four major risk factors for AF; obesity, hypertension, excessive alcohol consumption and smoking, and sleep apnea, significantly impact disease progression and treatment outcomes (Hindricks et al., 2021). Addressing these factors can improve symptoms and reduce complications.

First, obesity is strongly linked to AF severity. Research shows that losing at least 10% of body weight can greatly improve symptoms and overall health. An app could support weight management by tracking progress, offering personalized diet and exercise plans, and facilitating specialist referrals when needed. Cognitive behavioral therapy (CBT) and digital nudges have proven effective in promoting weight loss and increased physical activity (Valinskas et al., 2023; Fanaroff et al., 2023). Second, hypertension is a key contributor to AF and stroke risk, making blood pressure control essential. An app could help patients log and monitor their blood pressure, provide personalized lifestyle recommendations, and flag concerning trends for medical follow-up. CBT-based interventions have been shown to improve adherence to heart disease treatments (Trinquant et al., 2023). Third, excessive alcohol consumption and smoking increase AF risk, with alcohol having a stronger association (Tu et al., 2021). Reducing intake has no negative side effects and can enhance treatment effectiveness. An app could track consumption, offer motivational support, and connect patients with healthcare professionals. Digital interventions have successfully helped reduce alcohol and tobacco use (Garnett et al., 2018; Machulska et al., 2023). Finally, sleep apnea is closely linked to AF, and treating it improves ablation outcomes. An app could assist in early detection by providing risk assessment questionnaires and collecting oxygen saturation data, facilitating timely referrals for sleep studies when needed (Li et al., 2023). By integrating these tools, a digital health platform could take a proactive approach to AF management, helping patients make sustainable lifestyle changes and receive timely medical interventions.

The data collection post-op is meant to monitor patients after surgery, primarily to assess quality-of-life metrics. This includes overall well-being as well as quality-of-life related to arrhythmia and identifying late-onset complications. Not all complications arise within the two hours a patient spends in the operating room. Sometimes, a patient is sent to recovery after the surgery and the cardiologist specialist goes home. If it's a Friday, they might not be back until after the weekend, during which issues like groin complications or blood clots could develop without their knowledge. Some patients undergo multiple cardioversions without the cardiologist specialist even being aware, leading to unforeseen complications. That is why it is necessary to standardize the data collection for patients during surgery and post-op. Cardiologist specialists used to handle each case individually, which made it hard to see the bigger picture. A standardized follow-up process allows the specialists at the Department of Cardiology to answer basic questions such as: Are these complications common or rare? Do they occur in specific patient groups? Could the specialists change something to reduce the risk of recurrence?

Our interviews with the participants showed that they were interested in the data and would like to see it visualized. Based on that, we theorized that insightful data visualization combined with actionable feedback can improve decision-making and support continuous quality improvement of the healthcare service provided at the Department of Cardiology. Participants also mentioned that automatic feedback in the form of reminders or educational materials could prove useful in terms of behavior change. The results from the usability and user experience measures show there is a great need to improve in these areas. Participants mentioned that they could easily collect data through the registration form in the web application, but when it came to adjusting the forms or exporting data, they could not figure that out without help from the digital development team. Based on our combined findings in this paper, we summarize our main contributions into five design principles for designing and developing a digital health platform for data collection and symptom tracking in general and for designing and developing a digital health platform for patients with AF in particular:

1. **Detailed request for surgery:** It is important for the prioritization of patients into the surgery as soon as possible so that the patients can receive the most appropriate care based on the symptoms.
2. **Visualization of patient trajectory:** Healthcare professionals have limited time to monitor patients remotely and when a patient is flagged red the nurse wants to have easy access to their recent trajectory and to see the development from past measurements.
3. **Prioritization of patient waiting list based on real-time data:** From the initial request for surgery and until the patient is called into preparation for surgery many things can change in the health of the patient. Educating patients, monitoring their health, and encouraging changed behavior to support optimal prioritization.
4. **Uphold equality and inclusion throughout patient journey:** It is important to consider those who for some reason drop out or cannot participate in a digital patient journey.
5. **Quick access and visualization of quality indicators:** In order to support decision-making regarding the healthcare process delivery cardiology, specialists need to reflect on quality indicators that are easy to access and derive from databases such as the AF Registry.

Conclusion

In this paper, we show that quality data collection is the cornerstone to ensure patient safety and assess the efficiency of healthcare process delivery for patients with AF. From our findings, we derive five design principles for data collection and symptom tracking in general and for designing and developing a digital health platform for patients with AF in particular. The five design principles are the following: (i) detailed request for surgery, (ii) visualization of patient trajectory, (iii) prioritization of patient waiting list based on real-time data, (iv) upholding equality and inclusion throughout the patient journey, and (v) quick access and visualization of quality indicators. Further research includes exploring how other symptom tracking such as electrocardiograms (ECG) through smartwatches could contribute to the digital patient journey, looking at quantitative and qualitative measurements from AF patients. There is also a need to examine how the patient app with its reminders, questionnaires, and educational material can impact AF patients' knowledge about their disease and their health literacy. Finally, by using the AF registry there are opportunities to compare the three types of ablation surgeries (radiofrequency ablation, cryoablation, or pulsed field ablation) and their impact on quality-of-life, complications during surgery, and late-onset side effects.

References

- Elliott, A. D., Middeldorp, M. E., Van Gelder, I. C., Albert, C. M., & Sanders, P. (2023). Epidemiology and modifiable risk factors for atrial fibrillation. *Nature Reviews Cardiology*, 20(6), 404-417.
- Erlingsdottir, H. Y., Ketilsdottir, A., Hendriks, J. M., & Ingadottir, B. (2023). Disease-Related Knowledge and Need for Revision of Care for Patients with Atrial Fibrillation: A Cross Sectional Study. *Patient preference and adherence*, 2621-2630.
- Fanaroff, A. C., Patel, M. S., Chokshi, N., Coratti, S., Farraday, D., Norton, L., ... & Volpp, K. G. (2023). A randomized controlled trial of gamification, financial incentives, or both to increase physical activity among patients with elevated risk for cardiovascular disease: Rationale and design of the be active study. *American Heart Journal*, 260, 82-89.
- Garnett, C., Perski, O., Tombor, I., West, R., Michie, S., & Brown, J. (2018). Predictors of engagement, response to follow up, and extent of alcohol reduction in users of a smartphone app (drink less): secondary analysis of a factorial randomized controlled trial. *JMIR mHealth and uHealth*, 6(12), e11175.

Hindricks, G., Potpara, T., Dagres, N., Arbelo, E., Bax, J. J., Blomström-Lundqvist, C., ... & Watkins, C. L. (2021). 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS) The Task Force for the diagnosis and management of atrial fibrillation of the European Society of Cardiology (ESC) Developed with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC. *European heart journal*, 42(5), 373-498.

Hu, E. A., Nguyen, V., Langheier, J., & Shurney, D. (2020). Weight reduction through a digital nutrition and food purchasing platform among users with obesity: longitudinal study. *Journal of medical Internet research*, 22(9), e19634.

Kurtzman, G. W., Day, S. C., Small, D. S., Lynch, M., Zhu, J., Wang, W., ... & Patel, M. S. (2018). Social incentives and gamification to promote weight loss: the LOSE IT randomized, controlled trial. *Journal of general internal medicine*, 33, 1669-1675.

Laurens, M. C., Pieterse, M. E., Brusse-Keizer, M., Salemink, E., Ben Allouch, S., Bohlmeijer, E. T., & Postel, M. G. (2020). Alcohol avoidance training as a mobile app for problem drinkers: longitudinal feasibility study. *JMIR mHealth and uHealth*, 8(4), e16217.

Li, F., He, C. J., Ding, C. H., Wang, R. X., & Li, H. (2023). Continuous positive airway pressure therapy might be an effective strategy on reduction of atrial fibrillation recurrence after ablation in patients with obstructive sleep apnea: insights from the pooled studies. *Frontiers in Neurology*, 14, 1269945.

Machulska, A., Eiler, T. J., Haßler, B., Kleinke, K., Brück, R., Jahn, K., ... & Klucken, T. (2023). Mobile phone-based approach bias retraining for smokers seeking abstinence: a randomized-controlled study. *International Journal of Mental Health and Addiction*, 1-22.

Manning, V., Piercy, H., Garfield, J. B. B., Clark, S. G., Andrabi, M. N., & Lubman, D. I. (2021). A personalized approach bias modification smartphone app ("SWiPE") to reduce alcohol use: open-label feasibility, acceptability, and preliminary effectiveness study. *JMIR mHealth and uHealth*, 9(12), e31353.

Oldham, M., Beard, E., Loeberberg, G., Dinu, L., Angus, C., Burton, R., ... & Garnett, C. (2024). Effectiveness of a smartphone app (Drink Less) versus usual digital care for reducing alcohol consumption among increasing-and-higher-risk adult drinkers in the UK: a two-arm, parallel-group, double-blind, randomised controlled trial. *EClinicalMedicine*, 70.

Patel, M. S., Small, D. S., Harrison, J. D., Fortunato, M. P., Oon, A. L., Rareshide, C. A., ... & Hilbert, V. (2019). Effectiveness of behaviorally designed gamification interventions with social incentives for increasing physical activity among overweight and obese adults across the United States: the STEP UP randomized clinical trial. *JAMA internal medicine*, 179(12), 1624-1632.

Perez, M. V., Mahaffey, K. W., Hedlin, H., Rumsfeld, J. S., Garcia, A., Ferris, T., ... & Turakhia, M. P. (2019). Large-scale assessment of a smartwatch to identify atrial fibrillation. *New England Journal of Medicine*, 381(20), 1909-1917.

Rajakariar, K., Koshy, A. N., Sajeev, J. K., Nair, S., Roberts, L., & Teh, A. W. (2020). Accuracy of a smartwatch based single-lead electrocardiogram device in detection of atrial fibrillation. *Heart*, 106(9), 665-670.

Ringborg, A., Nieuwlaat, R., Lindgren, P., Jönsson, B., Fidan, D., Maggioni, A. P., ... & Crijns, H. J. (2008). Costs of atrial fibrillation in five European countries: results from the Euro Heart Survey on atrial fibrillation. *Europace*, 10(4), 403-411.

Sørensen, K., Pelikan, J. M., Röthlin, F., Ganahl, K., Slonska, Z., Doyle, G., ... & Brand, H. (2015). Health literacy in Europe: comparative results of the European health literacy survey (HLS-EU). *The European journal of public health*, 25(6), 1053-1058.

Trinquart, L., Liu, C., McManus, D. D., Nowak, C., Lin, H., Spartano, N. L., ... & Murabito, J. M. (2023). Increasing Engagement in the Electronic Framingham Heart Study: Factorial Randomized Controlled Trial. *Journal of medical Internet research*, 25, e40784.

Tu, S. J., Gallagher, C., Elliott, A. D., Linz, D., Pitman, B. M., Hendriks, J. M., ... & Wong, C. X. (2021). Risk thresholds for total and beverage-specific alcohol consumption and incident atrial fibrillation. *Clinical Electrophysiology*, 7(12), 1561-1569.

Valinskas, S., Nakrys, M., Aleknavičius, K., Jonusas, J., & Lileikienė, A. (2023). User engagement and weight loss facilitated by a mobile app: retrospective review of medical records. *JMIR Formative Research*, 7(1), e42266.

Virani, S. S., Alonso, A., Aparicio, H. J., Benjamin, E. J., Bittencourt, M. S., Callaway, C. W., ... & Tsao, C. W. (2021). Heart disease and stroke statistics-2021 update: a report from the American Heart Association. *Circulation*, 143(8), e254-e743.

Wasserlauf, J., You, C., Patel, R., Valys, A., Albert, D., & Passman, R. (2019). Smartwatch performance for the detection and quantification of atrial fibrillation. *Circulation: Arrhythmia and Electrophysiology*, 12(6), e006834.

Appendix D

A New Digital Health Platform for Patients With Inflammatory Bowel Disease: Preliminary Program Evaluation

Original Paper

A New Digital Health Program for Patients With Inflammatory Bowel Disease: Preliminary Program Evaluation

Saemundur Jon Oddsson¹, MD; Thrudur Gunnarsdottir¹, PhD; Lilja Gudrun Johannsdottir², MSc; Maria Lovisa Amundadottir¹, PhD; Arna Frimannsdottir³, MSc; Pauliina Molander^{4,5}, MD, PhD; Anna Karoliina Ylanne^{1,6}, RN; Anna Sigridur Islind², PhD; Maria Oskarsdottir², PhD; Tryggvi Thorgeirsson¹, MD

¹Sidekick Health Digital Therapeutics, Reykjavik, Iceland

²Reykjavik University, Reykjavik, Iceland

³Gallup, Reykjavik, Iceland

⁴Abdominal Center, Gastroenterology, Helsinki University Hospital, Helsinki, Finland

⁵University of Helsinki, Helsinki, Finland

⁶Pfizer, Kangasala, Finland

Corresponding Author:

Thrudur Gunnarsdottir, PhD

Sidekick Health Digital Therapeutics

Vallakór 4

Kópavogur

Reykjavik, 203

Iceland

Phone: 354 78 20 401

Email: thrudur@sidekickhealth.com

Abstract

Background: Inflammatory bowel disease (IBD) causes chronic inflammation of the gastrointestinal tract. IBD is characterized by an unpredictable disease course that varies greatly between individuals and alternates between the periods of relapse and remission. A low energy level (fatigue) is a common symptom, whereas stress and reduced sleep quality may be the triggering factors. Therapeutic guidelines call for effective disease assessment, early intervention, and personalized care using a treat-to-target approach, which may be difficult to achieve through typical time- and resource-constrained standard care. Providing patients with a digital health program that incorporates helpful self-management features and patient support to complement standard care may be optimal for improving the disease course.

Objective: This study aimed to perform a preliminary program evaluation, analyzing engagement and preliminary effectiveness and the effect on participants' energy levels (fatigue), stress, and sleep quality, of a newly developed 16-week digital health program (SK-311 and SK-321) for patients with IBD.

Methods: Adults with IBD were recruited to participate in a real-world, live, digital health program via Finnish IBD patient association websites and social media. No inclusion or exclusion criteria were applied for this study. Baseline characteristics were entered by the participants upon sign-up. Platform engagement was measured by tracking the participants' event logs. The outcome measures of stress, energy levels (fatigue), and quality of sleep were reported by participants through the platform.

Results: Of the 444 adults who registered for the digital health program, 205 (46.2%) were included in the intention-to-treat sample. The intention-to-treat participants logged events on average 41 times per week (5.9 times per day) during the weeks in which they were active on the digital platform. More women than men participated in the intervention (126/205, 88.7%). The mean age of the participants was 40.3 (SD 11.5) years, and their mean BMI was 27.9 (SD 6.0) kg/m². In total, 80 people provided the required outcome measures during weeks 12 to 16 (completers). Treatment completion was strongly predicted by the number of active days in week 1. Analysis of the completers (80/205, 39%) showed significant improvements for stress ($t_{79}=4.57$; $P<.001$; percentage change=-23.26%) and energy levels ($t_{79}=-2.44$; $P=.017$; percentage change=9.48%); however, no significant improvements were observed for quality of sleep ($t_{79}=-1.32$; $P=.19$).

Conclusions: These results support the feasibility of a digital health program for patients with IBD (SK-311 and SK-321) and suggest that treatment completion might have a substantial positive effect on patient-reported stress and energy levels in a

real-world setting. These findings are promising and provide initial support for using the Sidekick Health digital health program to supplement standard care for patients with IBD.

(*JMIR Form Res* 2023;7:e39331) doi: [10.2196/39331](https://doi.org/10.2196/39331)

KEYWORDS

inflammatory bowel disease; self-management; stress; fatigue; sleep; digital platform; digital therapeutics; real-world evidence; mobile phone

Introduction

Background

Inflammatory bowel disease (IBD) is a chronic disease often diagnosed early in life, during childhood or early adulthood [1]. The disease causes chronic inflammation of the gastrointestinal tract and clinically includes Crohn disease (CD), ulcerative colitis (UC), and unclassified IBD [2]. The incidence of IBD has been steadily rising worldwide, and it is considered one of the most common gastrointestinal diseases since the beginning of the 21st century [3]. Currently, the prevalence rates are highest in high-income countries (Europe and North America). However, over the last decades, its prevalence has also rapidly increased in low-income countries in Asia, Africa, and South America, emphasizing the increasing global burden of IBD [3,4].

Although the etiology of IBD remains largely unknown, it has been postulated to result from an uncontrolled immune response to a trigger in genetically prone individuals [5]. A trigger may include physiological and environmental factors such as diet, smoking, and stress, although the role of these factors in IBD is not entirely clear [6]. IBD is characterized by an unpredictable disease course that varies greatly between individuals and alternates between periods of active (relapse or flare-ups) and inactive (remission) disease [7]. The main symptoms include episodes of abdominal pain, diarrhea, rectal bleeding, weight loss, bowel urgency, and fatigue or lack of energy [1,5].

In a recent study [8], fatigue was reported as one of the most common disabling symptoms (86.9%) in adult patients with IBD. Furthermore, among patients with active disease, sleep problems, in addition to fatigue, were reported significantly more often than among patients in remission. Notably, stress was perceived by these patients as one of the primary triggers for IBD flare-ups [8], although reduced sleep quality and increased stress may also be a result of increased disease activity, pain, and fatigue during a flare-up [9,10]. Nevertheless, growing evidence suggests that reduced sleep quality, and particularly stress, may act as a promoting factor or relapse-triggering factor for IBD [11,12]. Reduced sleep quality and stress, therefore, seem to both *trigger* fatigue and other IBD symptoms and *result* from IBD, which points to a challenging and negative vicious circle between these interrelated factors.

In general, the unpredictable nature and often debilitating effects of various coexisting IBD symptoms lead patients to consistently report a low quality of life, high rates of health care use, and decreased productivity [13,14]. As there is currently no cure for IBD, treatments are primarily focused on symptom management, mucosal healing, and prevention of relapses to

improve patient quality of life and reduce the cost and burden of care. When applying conventional treatment approaches, almost 50% of the patients with CD and 16% of the patients with UC require intestinal surgery within 10 years of diagnosis [15,16]. Strikingly, up to 70% of individuals with CD and approximately 30% of those with UC will undergo gastrointestinal surgery at least once in their lives [17]. Therefore, a treat-to-target (T2T) approach, involving close monitoring of specific and objective measures of inflammation, has recently been advocated for IBD to improve long-term patient outcomes and reduce the need for surgery [18,19]. The T2T approach aims to reduce or prevent disease progression, prevent bowel damage, and promote mucosal healing by encouraging personalized care and early intervention [18,20]. However, T2T approaches are challenging to implement in clinical practice, where patients are only seen every few months for a limited amount of time. Providing patients with effective self-management strategies to complement outpatient care is therefore optimal.

Digital Health Programs

With the rapid rise of digitalization, digital health programs may be a promising medium for complementing traditional outpatient care and achieving a T2T goal. Digital health programs may facilitate improved communication between patients and health care providers. They may also provide patients with a means of tracking their symptoms and medical information, learning about their condition, and getting their questions answered. A study of the effects of smartphone interventions on long-term health management of chronic diseases found that patients who used digital interventions felt more secure about their condition, were more involved in their own care plans, and felt better taken care of outside the hospital or clinical setting [21]. Furthermore, digital interventions have been associated with decrease in health care costs and increase in convenience, productivity, and efficiency [22].

Studies investigating digital interventions for other chronic diseases such as diabetes, cardiovascular diseases, asthma, and gastrointestinal diseases have shown promising improvements in clinical outcomes in some, although not all, studies [23,24]. Specifically, the digital health programs delivered via the Sidekick Health digital therapeutics platform have previously shown promising results in treating obesity and type 2 diabetes [25,26]. Recent studies have noted that research into platforms for gastrointestinal diseases is limited compared with that for other chronic diseases and that most of the platforms have a lack of professional medical involvement [27]. Consequently, the evidence supporting IBD-specific platforms, particularly those involving medical professionals' involvement, is limited [28].

Study Objective

The Sidekick Health digital health program (SK-311 and SK-321) for IBD was developed based on evidence-based clinical guidelines with expert medical and behavioral involvement. The intervention was recently deployed for use among patients with IBD in Finland and launched for the first time in May 2020. This preliminary program evaluation was performed to assess engagement with the digital platform and to investigate the initial outcomes from this newly developed digital health program delivered via the Sidekick Health platform on participants' energy levels (fatigue), stress, and sleep quality, as all these factors play an important role in the course of IBD.

Methods

The Sidekick Health Digital Platform

Sidekick Health digital therapeutics (Sidekick) is a gamified digital platform that specializes in the delivery of evidence-based

digital health programs, including patient support and remote patient monitoring [26]. The platform combines an evidence-based clinical approach with behavioral economic principles and gamification [29]. Sidekick has developed a range of digital health programs for various therapeutic areas, including IBD. These interventions include personalized disease-specific education and treatment support, personalized behavior change goals, action plans, and feedback. Behavioral and medical experts have developed the interventions based on the latest evidence-based clinical guidelines and behavior change theories. The Sidekick platform [30] was designed to increase the frequency of healthy behaviors through goal setting, self-monitoring, and completion of health-related tasks (ie, gamification of tasks) in 4 main categories: nutrition (food), physical activity (move), stress management and psychoeducation (mind), and health (tracking of medications, supplements, and health-related outcomes; Figure 1). By completing gamified tasks, participants accumulate points that provide recognition (eg, in the form of badges) and altruistic rewards (eg, charitable water donations).

Figure 1. The Sidekick Health digital platform.



The IBD Digital Health Program (SK-311 and SK-321)

The overarching goal of this newly developed Sidekick Health's IBD digital health program (SK-311 for patients with UC and SK-321 for patients with CD) is to improve patients' well-being. Primary targets include reducing stress levels, improving quality of sleep, and improving energy levels. These targets are addressed through learning about disease, learning about cognitive behavioral strategies for behavior change, practicing mindfulness and meditation, increasing physical activity levels, and improving nutrition.

Previous studies have associated lifestyle changes with improved quality of life in patients with IBD [31]. In particular, a growing body of research has shown that patients with IBD might have psychosocial issues, including stress, anxiety, and depression, which can benefit from nonpharmacological interventions [32-34]. Among these, cognitive behavioral therapies, delivered

in person or web based [35,36], and mindfulness training [37] have shown encouraging results in improving psychological symptoms and the quality of life of patients with IBD.

The program contained 16 modules in the interventional program. Each module consisted of 1 week of intervention, which included 3-7 psychoeducational videos aimed at teaching or training new skills (skills related, among others, to resilience, self-care, nutritional habits, sleeping, physical activity, and how to change habits). The modules ran in a preset order, but participants could rewatch videos from previous modules in the app library. Each week, the patient was provided with automatic messages and personalized daily missions to complete certain tasks within the platform such as being physically active; practicing meditation and mindfulness; drinking water; eating well; watching psychoeducational videos; and rating their quality of sleep, stress, and energy levels. Patients are also provided with a community feed, where information is provided about

general health and IBD-related topics. In addition, a specialized IBD nurse monitors patient activity and sends out weekly feedback and motivational messages. Via the care portal, the nurse can see all the activity users log in the app. On the basis of the activity logged, in combination with the program's or participants' personal goals, the nurse provides personalized feedback. This feedback can be positive, negative, or instructional, although nurses are recommended to preferably combine instructional and positive feedback. For instance, in weeks that are focused on nutrition, participants may be asked to take pictures of their food and rate the healthiness and portion size. The nurse can then provide feedback on the food and the rating, perhaps suggesting healthier options or simply congratulating them on the healthy choice they made.

The *minimum* weekly in-app tasks that participants were encouraged to complete were to perform 150 minutes of physical activity; log stress, sleep, and energy levels 3 times per week; eat 2 healthy meals daily; perform 2 guided meditations and 1 mindfulness exercise per week; and walk 21,000 steps per week. The weekly number of steps is automatically personalized; the weekly number is adjusted up (or down) based on the participant's step count in the previous week (but will not be <3000 steps per day).

Data Collection

The data reported in this preliminary program evaluation were collected using the Sidekick Health platform in a real-world setting. The platform has restricted access to personal data, including encryption according to the military-grade 256-bit Advanced Encryption Standard, and is compliant with the relevant regulations (eg, General Data Protection Regulations). For this evaluation, anonymized data were extracted for further processing and analysis. No personal or identifiable data were included in the data set, which consisted of participant demographics and platform interactions.

Patient Recruitment

Potential participants were recruited from Finland via local IBD patient association websites and social media (Facebook and Instagram advertisements). Potential participants could click on posts through the websites and social media, which directed them to a landing page [38]. From there, they received a link with instructions on how to join the intervention. Participants who (1) joined the intervention, (2) provided informed consent, (3) logged at least 1 mission during week 1, and (4) provided the patient-reported outcome metrics of interest for this study during the first week of their intervention (stress, energy levels, and quality of sleep) constituted the intention-to-treat (ITT) sample [39]. Participants who also provided the outcome metrics between weeks 12 and 16 and were active for at least 12 weeks (80/205, 39%) were considered completers.

Measurements

Baseline Characteristics

Participants entered baseline demographic characteristics (date of birth, gender, height, and weight) upon platform sign-up (intervention onboarding). BMI (kg/m^2) was calculated based

on participants' height and weight, and age was calculated from participants' date of birth.

Engagement

Platform engagement was measured via participants' event logs (missions completed) within the platform (daily and weekly). A participant was considered active if at least 1 mission was completed during a specified period (either a day or a week). On the basis of the event logs, the average weekly platform interactions and average weekly interactions with mission categories (food, move, mind, and health) were calculated for each participant for their total active weeks. Of note, given the nature of our digital health program, engagement with the platform can be considered as a proxy for healthy behaviors adopted by the users in everyday life. Platform engagement during week 1 was quantified via participants' number of active days during the first week (range 1-7) and by how many onboarding activities (registering demographic information: age, gender, height, and weight) they performed during that week (ranging from 0 to 4).

Stress, Energy Levels, and Quality of Sleep

Patient-reported stress, energy levels, and quality of sleep were assessed using a Likert scale ranging from 0 to 10. Logging of stress, energy levels, and quality of sleep scores was encouraged daily (or at least 2 times per week) as part of the intervention's prescribed daily missions. The average reported scale score during the first week was used as the week 1 score (first observation), and the average reported scale score for a participant's last active week in the program was used as their last observation.

Statistical Analysis

Summary statistics were calculated for demographic and baseline characteristics to describe the overall sample and the subgroups designated as completers and noncompleters. To determine whether there were differences between the groups for these variables at baseline, 2-tailed *t* test and chi-square test were performed. Platform engagement was quantified for week 1 as follows: (1) the number of days active during week 1 and (2) the onboarding score. Platform engagement throughout the intervention was quantified as average weekly platform interactions and average weekly interactions for each category (mind, move, food, and health), including average weekly video lessons watched within the mind category. These variables were estimated by calculating mean and SD values across participants and median values and IQR for a more accurate description of nonnormal distributions.

Concerning the analysis of longitudinal clinically relevant outcomes (quality of sleep and energy and stress levels), only participants who completed the program were included in the analysis. Paired sample 2-tailed *t* tests assessed changes between baseline and program completion in self-reported stress, energy levels, and quality of sleep for the completers. The analyses were performed both with and without imputation using the method of last observation carried forward (LOCF) [40] for the missing data at follow-up (week 16). In addition, Cohen *d* and the percentage change (from baseline to the end of the program) were calculated. The Spearman rank correlation coefficient was

used to assess the associations between variables. All statistical analyses were conducted using R (version 4.1.2; R Foundation for Statistical Computing) and SPSS Statistics (version 27; IBM Corp; Build 1.0.0.1508; 64-bit edition). Visual inspection and graphic depiction of data were conducted using Seaborn version 0.10.1 (Python Software Foundation), a Python library for data visualization. The study flowchart was generated using Diagrams version 14.4.7 (JGraph Ltd).

Ethical Considerations

All participants provided informed consent before inclusion in the study. The platform had restricted access to personal data and was compliant with relevant regulations. For this program evaluation, anonymized data were extracted. The participants were not compensated for their participation in the study. The study was exempt from review by The National Bioethics Committee Board of Iceland (Ministry of Welfare). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki 2008.

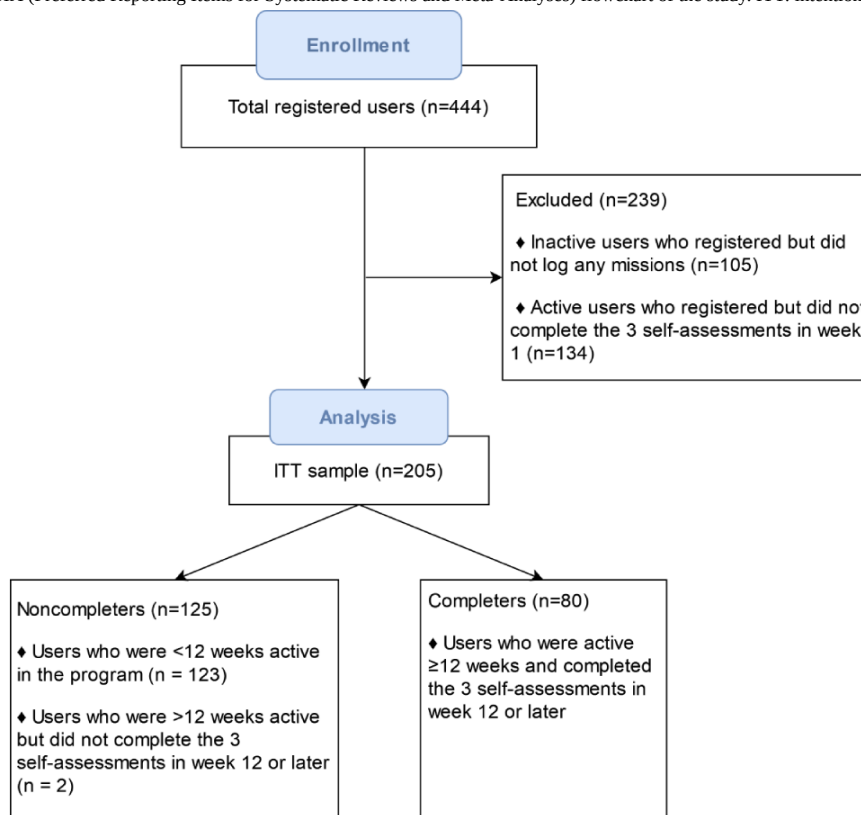
Results

Overview

The evaluation of the digital health program was launched in Finland on May 21, 2020. Initially, 444 people signed up and

provided informed consent. This preliminary program evaluation aimed to examine engagement and retention during the 16 weeks. In addition, the effects of the intervention on 3 clinical outcomes were tested: levels of stress, energy, and quality of sleep. A total of 239 participants who did not report these outcomes or did not log any mission during their first program week were excluded (Figure 2). The derived sample consisted of all potential participants who (1) signed up for the program; (2) provided informed consent; (3) completed the 3 self-assessments in week 1; and (4) had sufficient time from their sign-up date to go through 16 weeks when data were retrieved on February 1, 2021. These criteria resulted in an ITT sample size of 205 participants. Of these 205 participants, 80 (39%) completed the required outcome measures sometime during weeks 12 to 16 and were considered study completers, whereas the other 125 (61%) participants were considered noncompleters. All participants were included in the engagement and retention analyses, whereas only completers were included in the evaluation of clinical outcomes. Figure 2 provides the participant flow through the intervention.

Figure 2. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the study. ITT: intention-to-treat.



Participant Characteristics, Engagement, and Well-being at the Start of the Intervention

Baseline characteristics of the total group of participants (ITT sample: 205/205, 100%), completers (80/205, 39%), and noncompleters (125/205, 61%) are provided in Table 1. On average, the participants were aged 40.3 (SD 11.5) years and

had a BMI of 27.9 (SD 6.0) kg/m², with 63% (126/200) of participants being overweight or obese. There were significantly more women (126/142, 88.7%) than men (*P*<.05) among those who reported their gender (142/205, 69.3% of the ITT sample). Diagnosis (UC or CD) was not significantly different between the completers and noncompleters.

Table 1. Participants' baseline characteristics, engagement, and well-being (week 1).

	Total intention-to-treat sample (N=205)	Completers (n=80)	Noncompleters (n=125)	<i>P</i> value ^a
Characteristics				
Female				.63
Value, N ^a	142	63	79	
Value, n (%)	126 (88.7)	55 (87.3)	71 (89.9)	
Age (years)				.44
Value, N ^b	140	62	78	
Value, mean (SD)	40.29 (11.52)	39.45 (9.97)	40.96 (12.63)	
BMI (kg/m²)				.50
Value, N ^b	200	78	122	
Value, mean (SD)	27.85 (6.05)	27.49 (6.22)	28.08 (5.95)	
BMI groups, n (%)				.20
Underweight (BMI<18.5)	5 (2.4)	4 (5)	1 (0.8)	
Normal weight (BMI 18.5-24.9)	69 (33.7)	27 (34)	42 (33.6)	
Overweight (BMI 25-29.9)	64 (31.2)	27 (34)	37 (29.6)	
Obese (BMI≥30)	62 (30.2)	20 (25)	42 (33.6)	
Diagnosis, n (%)				
UC ^c	146 (71.2)	62 (78)	84 (67.2)	.11
CD ^d	59 (28.8)	18 (23)	41 (32.8)	.11
Engagement				
Onboarding score				.02
Value, N	205	80	125	
Value, mean (SD)	3.35 (0.95)	3.54 (0.81)	3.22 (1.01)	
Days active week 1				<.001
Value, N	205	80	125	
Value, mean (SD)	4.66 (2.37)	6.63 (0.79)	3.41 (2.19)	
Well-being, mean (SD)				
Stress	4.48 (2.23)	4.43 (1.89)	4.52 (2.43)	.76
Quality of sleep	6.10 (2.16)	6.16 (1.68)	6.06 (2.42)	.70
Energy levels	5.78 (1.79)	5.80 (1.65)	5.77 (1.89)	.89

^aComparison of data from completers and noncompleters.

^bNumber of participants who reported these data.

^cUC: ulcerative colitis.

^dCD: Crohn disease.

When looking at engagement during week 1, completers were active (logged events) for more days than noncompleters (mean

6.63, SD 0.79 vs 3.41, SD 2.19; *t*_{168.11}=−14.970; *P*<.001). Completers also had a higher onboarding score than

noncompleters, indicating that they filled out more background information during the first week (mean 3.54, SD 0.81 vs 3.22, SD 1.01; $t_{192.50}=-2.454$; $P=.02$). No other differences were observed between completers and noncompleters at week 1 (Table 1).

Participants' engagement during their first week of the intervention was determined by counting their number of active days in that week. Of the participants categorized as completers, 74% (59/80) visited the platform every day during their first week. Approximately all participants (77/80, 96%) were active for >4 days during that week. The distribution of active days in week 1 among noncompleters was more diverse than that among completers. Of the 125 noncompleters, 30.4% (n=38) visited the platform only once during their first week, and 70.4% (n=88) were active for <4 days (Multimedia Appendix 1).

Platform Engagement Throughout the Intervention

We analyzed the number of participants who accessed the platform each week throughout the intervention period (Multimedia Appendix 1). A total of 205 participants joined the intervention during week 1. Of the 205 participants, 141 (68.8%) accessed the platform in week 2 and 103 (50.2%) accessed the platform in week 5. From week 6 onward, most of the remaining participants were retained throughout the intervention.

The weekly number of events logged within the platform, within each platform category (food, move, mind, and health), and data on engagement with the lessons (psychoeducational videos) were tracked (Table 2). On average, participants logged 40.9 (SD 43.7) weekly interactions with the platform (median 26.4), with the most popular category being the food category, where participants logged an average of 18.1 (SD 21.4; median 10.0) interactions.

Table 2. Weekly platform engagement.

	Values, mean (SD)	Values, n ^a	Weekly average per participant, median (range; IQR)
Total interactions	40.89 (43.69)	205	26.40 (3.00-290.13; 11.94-53.60)
Food category	18.11 (21.36)	197	10.00 (0.64-120.14; 4.17-24.34)
Move category	9.36 (12.88)	186	7.42 (0.50-153.88; 2.72-12.22)
Mind category	11.84 (10.90)	205	8.50 (1.18-72.44; 4.00-16.38)
Videos watched	2.63 (1.67)	169	2.63 (0.06-7.67; 1.00-3.81)
Health category	5.10 (11.07)	127	1.19 (0.06-102.63; 0.31-4.67)

^aNumber of participants that entered data.

Analysis of Factors Affecting Intervention Completion

Both measures of engagement during week 1, namely, onboarding scores and active days during week 1, differed between completers and noncompleters at baseline ($P=.02$ and $P<.001$; Table 1), and their predictive value for treatment completion was further evaluated using logistic regression models (Table 3). In model A, the variable active days during

week 1 was a strong and significant predictor of completion status. However, the variable onboarding score was not a significant predictor of completion status after controlling for participants' active days during week 1. As shown in model B, the variable active days during week 1 predicted completion status to the same degree as including both variables (active days and onboarding score) in model A (Table 3).

Table 3. Logistic regression models for intervention completion.

	OR ^a (95% CI)	P value	Nagelkerke R ²
Model A intervention completion			
Predictor variables			0.606
Active days in week 1	2.965 (2.145-4.099)	<.001 ^b	
Onboarding score	1.211 (0.773-1.898)	.40	
Model B intervention completion			
Predictor variables			0.603
Active days in week 1	2.981 (2.157-4.120)	<.001	

^aOR: odds ratio.

^bThe $P<\text{corrected } \alpha \text{ is } .05/2=.025$.

Analysis of Changes in Quality of Sleep, Stress, and Energy Levels

The results for changes in quality of sleep, stress, and energy levels for the completers are summarized in Table 4. To exclude the possibility of biased results because of the LOCF imputation method, we performed a paired 2-tailed *t* test analysis both with and without LOCF imputation for missing data. With both approaches, we observed differences in the outcomes for stress,

which were significantly reduced (mean difference 1.03, *P*<.001 with LOCF; mean difference 1.16, *P*<.001 without LOCF), and for energy levels, which were significantly increased (mean difference -0.55, *P*=.017 with LOCF; mean difference -0.66, *P*=.01 without LOCF). No significant differences were observed in the outcome sleep quality, either with or without LOCF (Table 4). The distribution of ratings for stress, energy levels, and quality of sleep for the completers is shown in Figure 3.

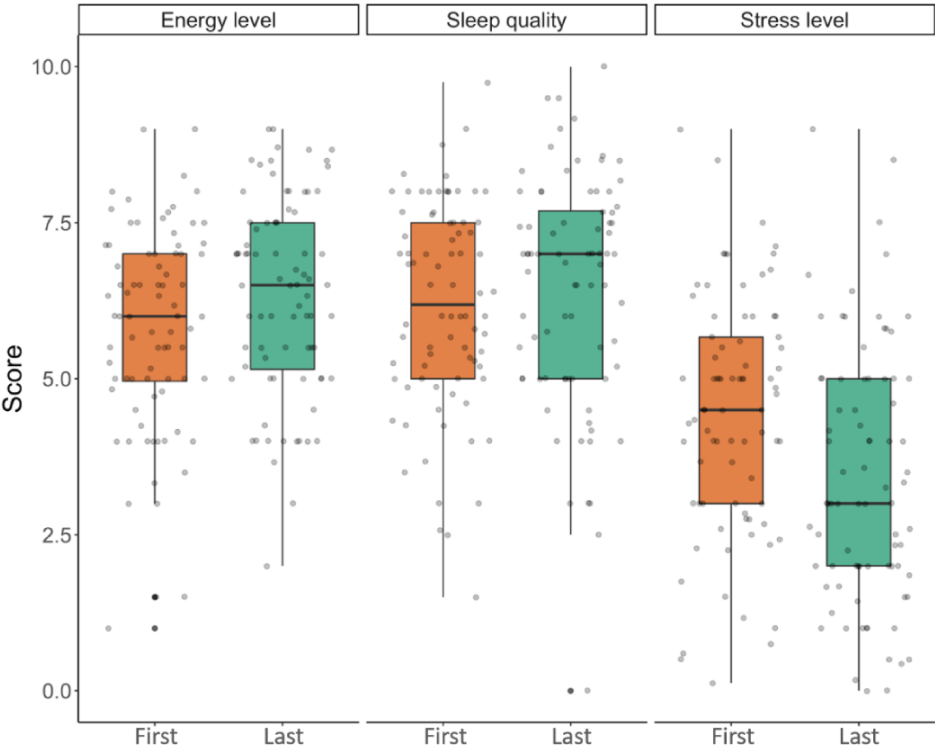
Table 4. Intervention outcomes sleep, stress, and energy in the completers.

	Mean difference (SD; 95% CI)	<i>t</i> test (<i>df</i>)	<i>P</i> value	Change from week 1 to last active week (%)	Cohen <i>d</i>
With LOCF^a					
Sleep	-0.28 (1.90; -0.71 to 0.14)	-1.32 (79)	.19	4.6	-0.147
Stress	1.03 (2.02; 0.58 to 1.48)	4.57 (79)	<.001 ^b	-23.26	0.511
Energy	-0.55 (2.02; -1 to -0.10)	-2.44 (79)	.017	9.48	-0.273
Without LOCF					
Sleep	-0.30 (1.96; -0.78 to 0.18)	-1.27 (68)	.21	4.92	-0.208
Stress	1.16 (2.11; 0.65 to 1.67)	4.54 (67)	<.001	-26.23	0.541
Energy	-0.66 (2.01; -1.16 to -0.17)	-2.67 (65)	.01	11.4	-0.34

^aLOCF: last observation carried forward.

^bItalicized *P* values indicate significant differences.

Figure 3. Ratings for energy levels, quality of sleep, and stress levels of completers from first to last observation in the completers group. Energy levels, quality of sleep, and stress levels were scored by participants on a scale of 0 to 10 at the first and last observations. The box plot represents the IQR with Tukey-style whiskers; the horizontal line in the box plot represents the median. Each dot represents the score of a single individual.



Associations Between Baseline Characteristics, Engagement Indicators, and Outcomes

For the completers, we also analyzed whether there were any associations between changes in the outcome variables (quality of sleep, stress, and energy levels) and the following variables at baseline: age; BMI; active days in week 1; onboarding score; quality of sleep, stress, and energy levels in week 1; and platform engagement. As shown in Table 5, we observed that for all outcomes, there were significant correlations between Δ

changes in the outcome measures and their respective baseline values (sleep $r=-0.5$, stress $r=0.43$, and energy $r=-0.56$). To test whether these correlations indicate a differential effect of the treatment according to the baseline levels, we recomputed them using the Oldham method [41]. The Spearman rank correlation values between Δ changes and their respective baselines with the Oldham method were as follows: sleep $r=-0.07$, stress $r=-0.13$, and energy $r=-0.008$. In addition, Δ for sleep quality correlated with age, stress level at baseline, and the number of food missions.

Table 5. Correlation between changes in outcome measures and study variables (n=80).

	Δ^a Sleep			Δ Stress			Δ Energy		
	ρ	<i>P</i> value	Values, n (%)	ρ	<i>P</i> value	Values, n (%)	ρ	<i>P</i> value	Values, n (%)
Age	0.27	.04 ^b	62 (78)	0	.98	62 (78)	0.11	.39	62 (78)
BMI	-0.21	.06	78 (98)	-0.03	.79	78 (98)	0.03	.81	78 (98)
Active days week 1	0.04	.72	80 (100)	-0.11	.35	80 (100)	0.05	.66	80 (100)
Onboarding score	0	.997	80 (100)	0.04	.74	80 (100)	0.11	.34	80 (100)
Sleep week 1	-0.5	<.001	80 (100)	0.11	.34	80 (100)	-0.19	.09	80 (100)
Stress week 1	-0.27	.02	80 (100)	0.43	<.001	80 (100)	-0.22	.05	80 (100)
Energy week 1	-0.1	.38	80 (100)	0.1	.39	80 (100)	-0.56	<.001	80 (100)
Total interactions	0.21	.06	80 (100)	0.06	.58	80 (100)	0.13	.26	80 (100)
Food	0.23	.04	80 (100)	0.05	.66	80 (100)	0.08	.50	80 (100)
Move	0.18	.11	80 (100)	0.09	.43	80 (100)	0.18	.11	80 (100)
Mind	0.16	.17	80 (100)	0.05	.64	80 (100)	0.1	.38	80 (100)
Video	0.08	.51	79 (99)	-0.13	.24	79 (99)	0.17	.15	79 (99)
Medical	-0.02	.90	76 (95)	-0.04	.70	76 (95)	0.09	.42	76 (95)

^a Δ is the difference between the scores of the previous week and week 1.

^bItalicized *P* values indicate significant differences.

Discussion

Principal Findings

In this preliminary program evaluation, we assessed for the first time the real-world benefits of the Sidekick Health’s IBD digital health program. Overall, we observed that participants were highly engaged with the treatment and that 39% (80/205) of the ITT sample completed a minimum of 12 weeks out of the 16-week intervention (completers). Of note, treatment completion was strongly predicted by the number of active days during week 1. In addition, we found that the completers showed statistically significant improvements in stress and energy levels from baseline to treatment completion.

Engagement with the platform is a prerequisite for reaping the benefits of participation. The participants in our sample engaged with the platform on average 41 times per week during the weeks in which they were active, which shows high engagement. Notably, the number of days a participant was active during the first week of the intervention was a robust predictor of intervention completion. Only 9% (7/80) of completers were active for <6 days during the first week. This presumably shows that participants with the highest motivation levels when starting

the intervention are, as expected, the most likely to complete the sign-up and onboarding process and then to continue throughout the intervention. Nevertheless, to inform future tailoring of the intervention to individual participants’ characteristics, reasons for participation, and motivation levels, improvements could include baseline measures of these factors to elucidate these findings.

Concerning the clinical outcomes, the findings from this initial evaluation are very promising given the high frequency of experiencing fatigue (low energy levels) by patients with IBD and its debilitating impact on quality of life [8]. In addition, as stress has been documented to be perceived by these patients as one of the leading causes of IBD flare-ups [8], observing reduced stress levels from the first to the last report is very encouraging. As existing IBD treatments are primarily focused on symptom management, prevention of relapses, and a T2T approach, providing patients with effective self-management strategies in the form of a digital platform to complement outpatient care may be optimal. On the basis of the results observed from this initial evaluation of the Sidekick Health real-world, live, digital health program, and consistent with results from other studies [22], this digital health program may

be promising as a supplement to standard care. This may facilitate the achievement of T2T goals in patients with IBD.

The observed correlations between each of the outcome changes (sleep, stress, and energy) and their baseline levels could suggest a differential effect of the digital health program according to the starting baseline value (eg, participants with lower energy levels at week 1 showed larger increases in energy levels at the end of the program). However, the negative associations between outcome changes and the corresponding baseline values of the same variables are most likely because of regression to the mean and mathematical coupling [42]. Indeed, when testing these associations using the Oldham method, we could not find any evidence for a differential digital health program effect for different baseline values [41].

Limitations

This study is a real-world evaluation of an ongoing, live intervention deployed at scale for patients with IBD in Finland. As a result, a limitation of the study is that the initial patient sample may be biased, perhaps leaning toward relatively younger patients, more female patients, and more motivated patients who used to engage with smartphone apps. However, this requires further investigation. Other interindividual differences may also contribute to selection bias; for example, personality traits such as openness and extraversion might be more prevalent among people interested in the new digital platform. In addition, participants with milder symptoms, and therefore higher energy levels, might show a higher adherence to the treatment. However, completers and noncompleters of the treatment did not differ on any of the disease-related variables (energy, sleep, and stress) at baseline. Another limitation of this study may be that the disease status of these patients was not medically ascertained. However, self-reported diagnosis was included, and percentages of UC and CD diagnoses were not found to differ between completers and noncompleters. The sample may also be biased because recruitment occurred through a patient association website and their social marketing efforts that may not have reached all patients with IBD. In addition, for this analysis, we only examined the participants who logged the outcomes of interest during week 1 (baseline). As a result, our sample did not include everyone who registered for the intervention but rather a selected group of participants.

For future evaluations, it would be interesting to examine IBD patient population characteristics in Finland and compare it with the characteristics of the sample that enters our platform. In addition, for our purposes, we will look into our onboarding process and the factors that may affect dropout and engagement in the first days of the intervention, as the data from this study seemed to indicate the importance of high engagement in week 1 for predicting completion. Determining ways to get participants “hooked” on the platform during week 1 might be worth investing in. The collection of additional data on participant characteristics may allow for a better comparison

with patients with IBD from the general population, which may help us find more varied methods for participant recruitment. The last notable limitation of this preliminary program evaluation is the lack of validation of the outcome metrics quality of sleep, stress, and energy levels and the absence of a control group for the longitudinal analysis. However, validation of these metrics against clinically validated measures is underway in ongoing research. Moreover, the effect of the digital health program on clinical outcomes in IBD will be tested in a future clinical trial with appropriate controls and randomization, which are beyond the scope of this preliminary program evaluation.

These limitations present an important caveat for generalizing our findings. In addition, the attrition rate of those who entered the intervention was relatively high, although high attrition and differential attrition are common in digital health research [43]. We consider the total retention rate of about 40% during the 16-week program as a fairly good result considering the framework and recruitment. In a recent analysis of retention data from >100,000 participants enrolled in 8 digital health studies, more than half of the participants dropped out after the first week (median retention 5.5 days) but with substantial variability across studies and according to participant characteristics (range 2-26 days) [44]. However, retention in future apps could be further improved by refining the recruitment strategy, by using further tailored in-app rewards, and by adding one-to-one coaching sessions with experts and physicians, thus improving patient monitoring and motivation. The scalability of digital interventions may allow for the recruitment of the sample sizes necessary for adequately powered mediation and moderation tests to explore potential predictors of intervention outcomes further. Of particular interest is the addition of more metrics (eg, disease state, flare-up or remission, pain perception, and symptom severity) to this platform, which will allow for more personalization of the intervention. As relapses in IBD are difficult to predict [7], ideally, adding more features for improving disease monitoring and improving the data collection process will allow us to gather data over time to identify variables that may predict relapse. This information could subsequently improve our interventions further and help prevent flare-ups by early symptom detection and treatment. This would help in maintaining remission and avoiding irreversible bowel damage and decreased quality of life owing to the long-term effects of IBD.

Conclusions

To conclude, this initial evaluation shows the feasibility and the potential benefits of a real-world digital health program for patients with IBD. Indeed, high engagement and retention with the digital platform seem to positively influence the patient-reported ratings of stress and energy levels. These findings are promising and provide initial support for the use of the digital health program for supplementing traditional outpatient care in the management of IBD.

Acknowledgments

The authors would like to thank the patients with inflammatory bowel disease who participated in this feasibility study and the Finnish IBD patient association for helping us recruit participants through their website and social media channels. The authors would also like to thank Esther van de Vosse of EV Science Consultant (the Netherlands) for providing editorial support.

Data Availability

The data sets generated or analyzed during this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

TT and SJO are cofounders of Sidekick Health digital therapeutics. TG, MLA, and AKY are employed by Sidekick Health digital therapeutics. AF is a previous employee of Sidekick Health. AKY received lecture, consultancy, and advisory board member fees from Pfizer, Sandoz, Takeda, and Tillotts Pharma. PM received lecture, consultancy, and advisory board member fees from Abbvie, Gilead, Janssen Cilag, MSD, Orion Pharma, Pfizer, Roche, Takeda, Tillotts Pharma, and Viartis.

Multimedia Appendix 1

Participation during the first week and overall during the intervention. (A) Number of active participants during the first week of intervention as a function of the number of active days. The distribution of the intention-to-treat (ITT) sample was split between completers and noncompleters, and 39% (80/205) of the participants were considered completers. (B) Number of active participants throughout the 16-week intervention (ie, participants performing at least 1 activity on the platform during a particular week). The percentage displayed at the top of each bar was calculated based on active participants versus the total ITT sample. Overall, 40% (82/205) of the participants were active during the 12th week of the intervention, and their participation was stable from that week onward.

[\[PNG File, 109 KB-Multimedia Appendix 1\]](#)

References

- Stein DJ, Shaker R. Inflammatory Bowel Disease: A Point of Care Clinical Guide. Cham, Switzerland: Springer; 2015.
- Fakhoury M, Negulj R, Mooranian A, Al-Salami H. Inflammatory bowel disease: clinical aspects and treatments. *J Inflamm Res* 2014 Jun 23;7:113-120 [[FREE Full text](#)] [doi: [10.2147/JIR.S65979](#)] [Medline: [25075198](#)]
- Ng SC, Shi HY, Hamidi N, Underwood FE, Tang W, Benchimol EI, et al. Worldwide incidence and prevalence of inflammatory bowel disease in the 21st century: a systematic review of population-based studies. *Lancet* 2017 Dec 23;390(10114):2769-2778. [doi: [10.1016/S0140-6736\(17\)32448-0](#)] [Medline: [29050646](#)]
- Kaplan GG. The global burden of IBD: from 2015 to 2025. *Nat Rev Gastroenterol Hepatol* 2015 Dec;12(12):720-727. [doi: [10.1038/nrgastro.2015.150](#)] [Medline: [26323879](#)]
- Guan Q. A comprehensive review and update on the pathogenesis of inflammatory bowel disease. *J Immunol Res* 2019 Dec 1;2019:7247238 [[FREE Full text](#)] [doi: [10.1155/2019/7247238](#)] [Medline: [31886308](#)]
- Sairenji T, Collins KL, Evans DV. An update on inflammatory bowel disease. *Prim Care* 2017 Dec;44(4):673-692. [doi: [10.1016/j.pop.2017.07.010](#)] [Medline: [29132528](#)]
- Chang S, Malter L, Hudesman D. Disease monitoring in inflammatory bowel disease. *World J Gastroenterol* 2015 Oct 28;21(40):11246-11259 [[FREE Full text](#)] [doi: [10.3748/wjg.v21.i40.11246](#)] [Medline: [26523100](#)]
- Vegni E, Gilardi D, Bonovas S, Corró BE, Menichetti J, Leone D, et al. Illness perception in inflammatory bowel disease patients is different between patients with active disease or in remission: a prospective cohort study. *J Crohns Colitis* 2019 Mar 30;13(4):417-423. [doi: [10.1093/ecco-jcc/ijy183](#)] [Medline: [30517669](#)]
- Graff LA, Vincent N, Walker JR, Clara I, Carr R, Ediger J, et al. A population-based study of fatigue and sleep difficulties in inflammatory bowel disease. *Inflamm Bowel Dis* 2011 Sep;17(9):1882-1889. [doi: [10.1002/ibd.21580](#)] [Medline: [21830266](#)]
- Jelsness-Jørgensen LP, Bernklev T, Henriksen M, Torp R, Moum B. Chronic fatigue is associated with increased disease-related worries and concerns in inflammatory bowel disease. *World J Gastroenterol* 2012 Feb 07;18(5):445-452 [[FREE Full text](#)] [doi: [10.3748/wjg.v18.i5.445](#)] [Medline: [22346250](#)]
- Sun Y, Li L, Xie R, Wang B, Jiang K, Cao H. Stress triggers flare of inflammatory bowel disease in children and adults. *Front Pediatr* 2019 Oct 24;7:432 [[FREE Full text](#)] [doi: [10.3389/fped.2019.00432](#)] [Medline: [31709203](#)]
- Zargar A, Gooraji SA, Keshavarzi B, Haji Aghamohammadi AA. Effect of irritable bowel syndrome on sleep quality and quality of life of inflammatory bowel disease in clinical remission. *Int J Prev Med* 2019 Jan 15;10:10 [[FREE Full text](#)] [doi: [10.4103/ijpvm.IJPVM_364_17](#)] [Medline: [30774844](#)]
- Bernklev T, Jahnsen J, Lygren I, Henriksen M, Vatn M, Moum B. Health-related quality of life in patients with inflammatory bowel disease measured with the short form-36: psychometric assessments and a comparison with general population norms. *Inflamm Bowel Dis* 2005 Oct;11(10):909-918. [doi: [10.1097/01.mib.0000179467.01748.99](#)] [Medline: [16189421](#)]

14. Cohen R, Skup M, Ozbay AB, Rizzo J, Yang M, Diener M, et al. Direct and indirect healthcare resource utilization and costs associated with ulcerative colitis in a privately-insured employed population in the US. *J Med Econ* 2015 Jun;18(6):447-456 [FREE Full text] [doi: [10.3111/13696998.2015.1021353](https://doi.org/10.3111/13696998.2015.1021353)] [Medline: [25728698](https://pubmed.ncbi.nlm.nih.gov/25728698/)]
15. Frolkis AD, Dykeman J, Negrón ME, Debruyne J, Jette N, Fiest KM, et al. Risk of surgery for inflammatory bowel diseases has decreased over time: a systematic review and meta-analysis of population-based studies. *Gastroenterology* 2013 Nov;145(5):996-1006. [doi: [10.1053/j.gastro.2013.07.041](https://doi.org/10.1053/j.gastro.2013.07.041)] [Medline: [23896172](https://pubmed.ncbi.nlm.nih.gov/23896172/)]
16. Annese V, Duricova D, Gower-Rousseau C, Jess T, Langholz E. Impact of new treatments on hospitalisation, surgery, infection, and mortality in IBD: a focus paper by the epidemiology committee of ECCO. *J Crohns Colitis* 2016 Feb;10(2):216-225. [doi: [10.1093/ecco-jcc/jjv190](https://doi.org/10.1093/ecco-jcc/jjv190)] [Medline: [26520163](https://pubmed.ncbi.nlm.nih.gov/26520163/)]
17. Kemp K, Dibley L, Chauhan U, Greveson K, Jäghult S, Ashton K, et al. Second N-ECCO consensus statements on the European nursing roles in caring for patients with Crohn's disease or ulcerative colitis. *J Crohns Colitis* 2018 Jun 28;12(7):760-776. [doi: [10.1093/ecco-jcc/jjy020](https://doi.org/10.1093/ecco-jcc/jjy020)] [Medline: [29509882](https://pubmed.ncbi.nlm.nih.gov/29509882/)]
18. Drescher H, Lissos T, Hajisafari E, Evans ER. Treat-to-target approach in inflammatory bowel disease: the role of advanced practice providers. *J Nurse Pract* 2019 Oct;15(9):676-681 [FREE Full text] [doi: [10.1016/j.nurpra.2019.07.015](https://doi.org/10.1016/j.nurpra.2019.07.015)]
19. Allen PB, Olivera P, Emery P, Moulin D, Jouzeau JY, Netter P, et al. Review article: moving towards common therapeutic goals in Crohn's disease and rheumatoid arthritis. *Aliment Pharmacol Ther* 2017 Apr;45(8):1058-1072. [doi: [10.1111/apt.13995](https://doi.org/10.1111/apt.13995)] [Medline: [28247573](https://pubmed.ncbi.nlm.nih.gov/28247573/)]
20. Peyrin-Biroulet L, Sandborn W, Sands BE, Reinisch W, Bemelman W, Bryant RV, et al. Selecting therapeutic targets in inflammatory bowel disease (STRIDE): determining therapeutic goals for treat-to-target. *Am J Gastroenterol* 2015 Sep;110(9):1324-1338. [doi: [10.1038/ajg.2015.233](https://doi.org/10.1038/ajg.2015.233)] [Medline: [26303131](https://pubmed.ncbi.nlm.nih.gov/26303131/)]
21. Wang J, Wang Y, Wei C, Yao NA, Yuan A, Shan Y, et al. Smartphone interventions for long-term health management of chronic diseases: an integrative review. *Telemed J E Health* 2014 Jun;20(6):570-583. [doi: [10.1089/tmj.2013.0243](https://doi.org/10.1089/tmj.2013.0243)] [Medline: [24787747](https://pubmed.ncbi.nlm.nih.gov/24787747/)]
22. Ventola CL. Mobile devices and apps for health care professionals: uses and benefits. *P T* 2014 May;39(5):356-364 [FREE Full text] [Medline: [24883008](https://pubmed.ncbi.nlm.nih.gov/24883008/)]
23. Whitehead L, Seaton P. The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. *J Med Internet Res* 2016 May 16;18(5):e97 [FREE Full text] [doi: [10.2196/jmir.4883](https://doi.org/10.2196/jmir.4883)] [Medline: [27185295](https://pubmed.ncbi.nlm.nih.gov/27185295/)]
24. Helsel BC, Williams JE, Lawson K, Liang J, Markowitz J. Telemedicine and mobile health technology are effective in the management of digestive diseases: a systematic review. *Dig Dis Sci* 2018 Jun;63(6):1392-1408. [doi: [10.1007/s10620-018-5054-z](https://doi.org/10.1007/s10620-018-5054-z)] [Medline: [29663265](https://pubmed.ncbi.nlm.nih.gov/29663265/)]
25. Hilmarsdóttir E, Sigurðardóttir ÁK, Arnardóttir RH. A digital lifestyle program in outpatient treatment of type 2 diabetes: a randomized controlled study. *J Diabetes Sci Technol* 2021 Sep;15(5):1134-1141 [FREE Full text] [doi: [10.1177/1932296820942286](https://doi.org/10.1177/1932296820942286)] [Medline: [32680441](https://pubmed.ncbi.nlm.nih.gov/32680441/)]
26. Thorgeirsson T, Torfadóttir JE, Egilsson E, Oddsson S, Gunnarsdóttir T, Aspelund T, et al. Randomized trial for weight loss using a digital therapeutic application. *J Diabetes Sci Technol* 2022 Sep;16(5):1150-1158. [doi: [10.1177/19322968211000815](https://doi.org/10.1177/19322968211000815)] [Medline: [33736484](https://pubmed.ncbi.nlm.nih.gov/33736484/)]
27. Con D, De Cruz P. Mobile phone apps for inflammatory bowel disease self-management: a systematic assessment of content and tools. *JMIR mhealth uhealth* 2016 Feb 01;4(1):e13 [FREE Full text] [doi: [10.2196/mhealth.4874](https://doi.org/10.2196/mhealth.4874)] [Medline: [26831935](https://pubmed.ncbi.nlm.nih.gov/26831935/)]
28. Ullman TA, Atreja A. Building evidence for care beyond the medical centre. *Lancet* 2017 Sep 02;390(10098):919-920. [doi: [10.1016/S0140-6736\(17\)31857-3](https://doi.org/10.1016/S0140-6736(17)31857-3)] [Medline: [28716311](https://pubmed.ncbi.nlm.nih.gov/28716311/)]
29. Thorgeirsson T, Kawachi I. Behavioral economics: merging psychology and economics for lifestyle interventions. *Am J Prev Med* 2013 Feb;44(2):185-189. [doi: [10.1016/j.amepre.2012.10.008](https://doi.org/10.1016/j.amepre.2012.10.008)] [Medline: [23332337](https://pubmed.ncbi.nlm.nih.gov/23332337/)]
30. Clinical treatments - digitally delivered. Sidekick Health. 2020. URL: <https://sidekickhealth.com/> [accessed 2022-05-06]
31. Rozich JJ, Holmer A, Singh S. Effect of lifestyle factors on outcomes in patients with inflammatory bowel diseases. *Am J Gastroenterol* 2020 Jun;115(6):832-840 [FREE Full text] [doi: [10.14309/ajg.0000000000000608](https://doi.org/10.14309/ajg.0000000000000608)] [Medline: [32224703](https://pubmed.ncbi.nlm.nih.gov/32224703/)]
32. Cámara RJ, Ziegler R, Bégre S, Schoepfer AM, von Känel R, Swiss Inflammatory Bowel Disease Cohort Study (SIBDCS) group. The role of psychological stress in inflammatory bowel disease: quality assessment of methods of 18 prospective studies and suggestions for future research. *Digestion* 2009;80(2):129-139 [FREE Full text] [doi: [10.1159/000226087](https://doi.org/10.1159/000226087)] [Medline: [19657191](https://pubmed.ncbi.nlm.nih.gov/19657191/)]
33. Häuser W, Moser G, Klose P, Mikocka-Walus A. Psychosocial issues in evidence-based guidelines on inflammatory bowel diseases: a review. *World J Gastroenterol* 2014 Apr 07;20(13):3663-3671 [FREE Full text] [doi: [10.3748/wjg.v20.i13.3663](https://doi.org/10.3748/wjg.v20.i13.3663)] [Medline: [24707152](https://pubmed.ncbi.nlm.nih.gov/24707152/)]
34. Davis SP, Bolin LP, Crane PB, Crandell J. Non-pharmacological interventions for anxiety and depression in adults with inflammatory bowel disease: a systematic review and meta-analysis. *Front Psychol* 2020 Nov 05;11:538741 [FREE Full text] [doi: [10.3389/fpsyg.2020.538741](https://doi.org/10.3389/fpsyg.2020.538741)] [Medline: [33250803](https://pubmed.ncbi.nlm.nih.gov/33250803/)]
35. Mikocka-Walus A, Bampton P, Hetzel D, Hughes P, Esterman A, Andrews JM. Cognitive-behavioural therapy has no effect on disease activity but improves quality of life in subgroups of patients with inflammatory bowel disease: a pilot

- randomised controlled trial. BMC Gastroenterol 2015 May 02;15:54 [FREE Full text] [doi: [10.1186/s12876-015-0278-2](https://doi.org/10.1186/s12876-015-0278-2)] [Medline: [25934170](https://pubmed.ncbi.nlm.nih.gov/25934170/)]
36. McCombie A, Gearry R, Andrews J, Mulder R, Mikocka-Walus A. Does computerized cognitive behavioral therapy help people with inflammatory bowel disease? A randomized controlled trial. Inflamm Bowel Dis 2016 Jan;22(1):171-181 [FREE Full text] [doi: [10.1097/MIB.0000000000000567](https://doi.org/10.1097/MIB.0000000000000567)] [Medline: [26360545](https://pubmed.ncbi.nlm.nih.gov/26360545/)]
 37. Jedel S, Hoffman A, Merriman P, Swanson B, Voigt R, Rajan KB, et al. A randomized controlled trial of mindfulness-based stress reduction to prevent flare-up in patients with inactive ulcerative colitis. Digestion 2014;89(2):142-155 [FREE Full text] [doi: [10.1159/000356316](https://doi.org/10.1159/000356316)] [Medline: [24557009](https://pubmed.ncbi.nlm.nih.gov/24557009/)]
 38. Sidekick, hyvän olon tekoja. Sidekick Health. 2020. URL: <https://ibd.fi/sidekick/> [accessed 2021-03-17]
 39. Gupta SK. Intention-to-treat concept: a review. Perspect Clin Res 2011 Jul;2(3):109-112 [FREE Full text] [doi: [10.4103/2229-3485.83221](https://doi.org/10.4103/2229-3485.83221)] [Medline: [21897887](https://pubmed.ncbi.nlm.nih.gov/21897887/)]
 40. Salkind NJ. Encyclopedia of Research Design. Thousand Oaks, CA, USA: Sage Publications; 2010.
 41. Oldham PD. A note on the analysis of repeated measurements of the same subjects. J Chronic Dis 1962 Oct;15:969-977. [doi: [10.1016/0021-9681\(62\)90116-9](https://doi.org/10.1016/0021-9681(62)90116-9)] [Medline: [13939936](https://pubmed.ncbi.nlm.nih.gov/13939936/)]
 42. Tu YK, Gilthorpe MS. Revisiting the relation between change and initial value: a review and evaluation. Stat Med 2007 Jan 30;26(2):443-457. [doi: [10.1002/sim.2538](https://doi.org/10.1002/sim.2538)] [Medline: [16526009](https://pubmed.ncbi.nlm.nih.gov/16526009/)]
 43. Linardon J, Fuller-Tyszkiewicz M. Attrition and adherence in smartphone-delivered interventions for mental health problems: a systematic and meta-analytic review. J Consult Clin Psychol 2020 Jan;88(1):1-13. [doi: [10.1037/ccp0000459](https://doi.org/10.1037/ccp0000459)] [Medline: [31697093](https://pubmed.ncbi.nlm.nih.gov/31697093/)]
 44. Pratap A, Neto EC, Snyder P, Stepnowsky C, Elhadad N, Grant D, et al. Indicators of retention in remote digital health studies: a cross-study evaluation of 100,000 participants. NPJ Digit Med 2020 Feb 17;3:21 [FREE Full text] [doi: [10.1038/s41746-020-0224-8](https://doi.org/10.1038/s41746-020-0224-8)] [Medline: [32128451](https://pubmed.ncbi.nlm.nih.gov/32128451/)]

Abbreviations

CD: Crohn disease
IBD: inflammatory bowel disease
ITT: intention-to-treat
LOCF: last observation carried forward
T2T: treat-to-target
UC: ulcerative colitis

Edited by A Mavragani; submitted 09.05.22; peer-reviewed by M Babashahi; comments to author 22.12.22; revised version received 27.02.23; accepted 28.02.23; published 28.04.23

Please cite as:

Oddsson SJ, Gunnarsdottir T, Johannsdottir LG, Amundadottir ML, Frimannsdottir A, Molander P, Ylanne AK, Islind AS, Oskarsdottir M, Thorgeirsson T

A New Digital Health Program for Patients With Inflammatory Bowel Disease: Preliminary Program Evaluation

JMIR Form Res 2023;7:e39331

URL: <https://formative.jmir.org/2023/1/e39331>

doi: [10.2196/39331](https://doi.org/10.2196/39331)

PMID: [37115598](https://pubmed.ncbi.nlm.nih.gov/37115598/)

©Saemundur Jon Oddsson, Thrudur Gunnarsdottir, Lilja Gudrun Johannsdottir, Maria Lovisa Amundadottir, Arna Frimannsdottir, Pauliina Molander, Anna Karoliina Ylanne, Anna Sigridur Islind, Maria Oskarsdottir, Tryggvi Thorgeirsson. Originally published in JMIR Formative Research (<https://formative.jmir.org>), 28.04.2023. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR Formative Research, is properly cited. The complete bibliographic information, a link to the original publication on <https://formative.jmir.org>, as well as this copyright and license information must be included.

© 2023. This work is licensed under

<https://creativecommons.org/licenses/by/4.0/> (the “License”).

Notwithstanding the ProQuest Terms and Conditions, you may use this content in accordance with the terms of the License.

Appendix E

Digital Nudging in Digital Health Technologies: A Systematic Review

Digital Nudging in Digital Health Technologies: A Systematic Review

Lilja Guðrún Jóhannsdóttir,

Department of Computer Science, Reykjavík University, liljaj20@ru.is, Iceland, ORCID 0000-0002-2076-3289

Steinunn Gróa Sigurðardóttir,

Dep. of Computer Science, Reykjavík University, steinunngroa@ru.is, Iceland, ORCID 0000-0002-3576-0857

María Óskarsdóttir,

Department of Computer Science, Reykjavík University, mariaoskars@ru.is, Iceland, ORCID 0000-0001-5095-5356

Anna Sigríður Islind,

Department of Computer Science, Reykjavík University, annasi@ru.is, Iceland, ORCID 0000-0002-4563-0001

Abstract

Purpose: The use of digital health technologies (DHT) combined with digital nudging is rapidly growing. Digital nudges have the potential to impact patient treatment, safety, and management. DHTs, such as mobile applications in combination with smartwatches and other self-trackers, can increase the quality of life of patients. Although digital nudges have been explored and studied in the context of treatment, there is a need to further explore how DHT that rely on digital nudges can be utilized in healthcare settings and if they are effective. Considering that, there is a need for a systematic literature review on the topic. We synthesize research on how digital nudging is utilized to enhance DHTs by addressing the research question: *“How can digital nudges be used within digital health technologies in healthcare settings to support patient treatment, safety, and management?”* The approach was to systematically analyze the use of digital nudging within the domain of healthcare settings.

Methods: A systematic review based on the PRISMA guidelines was conducted by searching the following databases: Scopus, PubMed, ACM Digital Library, Web of Science, and IEEE Xplore. In total, there were 3655 papers after excluding duplicates. Through a selection process, we arrived at 151 peer-reviewed papers that were read, after which the last inclusion step in the systematic review yielded 62 papers that were included in the analysis.

Results: First, we classified these contributions across established digital nudging categories, as well as summarized the main characteristics of the DHTs. Second, our findings indicated that digital nudging within DHTs was prominently used for patients in the healthcare settings of (i) metabolic and physical activity, (ii) treatment adherence, (iii) addiction disease, (iv) rehabilitation, (v) mental health, and (vi) children’s health. Third, we showed that digital nudges are effective in some healthcare settings when applied to DHTs. They can support the treatment and management of patients where the goal is an improved lifestyle, i.e., more exercise, weight loss, less drinking and smoking. They support documentation and, therefore, patient safety in the adherence to treatment and mental health interventions.

Conclusions: In this paper, we show that digital nudges are used in various ways within DHTs to address patient treatment, safety, and management. There is a need to further explore opportunities for digital nudges for the rehabilitation of patients and successful methods for working with children. There is a need to carefully consider that digital nudges embedded into DHTs are powerful and should be used responsibly with vulnerable users, such as patients and children. The main contribution is an in-depth analysis of the literature that engages with the intersection between digital nudging and digital health technologies.

Keywords: Digital Nudging, Digital Health Technologies, Patient Safety, Patient Management

Introduction

Background

Changes in behavior or lifestyle can, in some cases, prevent or treat diseases such as heart disease [1], cancer [2], diabetes [3], obesity [4], asthma [5], and mental illnesses [6]. The fast growth of patients living with diseases presents large-scale challenges for the healthcare system, which need to be tackled by innovative solutions. One possible pathway forward is to rely on the patient's participation in self-care to a larger extent. To do that, healthcare delivery needs to extend beyond the walls of the healthcare system and into the patient's lives, i.e., through digital means [7]. Opening the possibility of using digital means as an embedded element in healthcare delivery allows for interesting elements to be incorporated, such as nudging patients towards specific behaviors that may eradicate or alleviate their symptoms and enhance their lives to some extent. Nudging theory, which derives from behavioral economics, acknowledges that the "choice architecture alters people's behavior in a predictable way without forbidding any options" [8]. Small changes in the choice environment can influence people's choices and "nudge" them into behaving in a certain way [9]. People use shortcuts that help simplify the decision-making process, and nudging takes advantage of that. These shortcuts are referred to as heuristics or cognitive biases [10]. Nudging relies mainly on System 1 reasoning (automatic system), which refers to quick, intuitive, and automatic responses, as opposed to System 2 reasoning (reflective system), which is a slower and more deliberative process [11]. Nudging is increasingly used to produce health-improving behavioral changes in digital health technologies (DHTs) and shows the potential to improve health outcomes among those living with chronic diseases [12, 13]. Furthermore, "digital nudging" is an approach where people's cognitive biases are actively used and applied to the design elements in the user interface of a digital choice environment to affect the choices of users [9, 14]. The nature of DHTs, independent of whether they are in the form of a mobile application or sensor-based technologies such as wearables, nearables, or other DHTs, allows for scalable and readily available solutions for patients, and digital nudging can be embedded within those.

Nudging in general and digital nudging in particular are popular types of interventions to produce behaviors that result in health improvements in populations [15-17]. There are a few literature reviews on nudging that focus on the context of health [18-24]. One study showed that nudges resulted in an average 15.3% increase in healthier dietary or nutritional choices [19], while another study showed that interventions with nudges were more effective at reducing unhealthy eating than increasing healthy eating or reducing total eating [24]. However, these literature reviews were on traditional nudges, albeit not embedded into DHTs and thus, not digital nudges. Another recent review discussed the effectiveness [25] and the categorization of nudging and nudging approaches [26], however, not within DHT. Furthermore, there is a review of the digital landscape of nudging, which focuses specifically on empirical studies of digital nudges [27]. However, the research on the intersection between digital nudging and digital health technologies is rapidly growing and lacks a focus on digital nudges specifically; ergo, systematic literature reviews on the topic are missing. Considering that, we offer a systematic literature review based on the PRISMA criteria of the literature on digital nudging within the domain of DHTs.

This systematic review summarizes the research of digital nudges applied in DHTs designed and developed for patients in healthcare settings. The focus is on the research question: *"How can digital nudging be used within digital health technologies in healthcare settings to support patient treatment, safety, and management?"* We classify these contributions across established digital nudging categories (see Table 1 for clarification).

Table 1. Common examples of cognitive biases and heuristics that can be applied to promote behavior or attitudinal change in healthcare settings.

Nudge Category	Definition	Example of Nudge as Behavioral or Attitudinal Intervention
Feedback	Provides information about the past or current behavior of a user [28].	Notification to a user that he has completed 10,000 steps today or perhaps three days in a row.
Priming	Some underlying psychological mechanisms such as priming [29].	Swiping images on a screen associated with unhealthy behavior away from the body and images of preferred behavior toward the body.
Social reference	Providing references to how other users behave, thereby creating a social norm. Also, the tendency to want to appeal to the expectations of others [30].	Receiving information about the progress of other cancer survivors. Being monitored remotely by healthcare professionals or sharing progress with a buddy.
Precommitment	Commitments by users will motivate them to behave in a way that is consistent with the commitments [31].	Setting goals for healthy eating, regular exercise, or no smoking.
Disclosure	Adding information that is accessible, clear, and relevant to the choice that the user is about to make [32].	Sharing relevant information about diseases and/or the benefits of getting enough sleep and eating certain types of foods.
Simplification	Behavior can be encouraged or discouraged by removing or adding friction [33].	Making it more difficult for children dealing with problematic smartphone usage to access certain apps. Using sensors to conveniently share information about adherence with healthcare professionals.
Loss aversion	People assign more value to something that is going to be more difficult to acquire in the future [34].	Losing points for unhealthy behavior instead of gaining points for making healthy choices.
Warnings	Different kinds of warnings and graphics assist users by grabbing their attention to various risks and consequences [35].	Sharing graphics and information about the danger of smoking or not adhering to treatment.
Default	Design the choice architecture in such a way that the default behavior is the desired behavior [36].	Preselect healthy food options in a grocery app for people who are overweight.

Methods

Information Sources and Eligibility Criteria

We used the PICO tool to develop the research question [37], where the population (patients with underlying disease), intervention (digital nudges in DHTs), comparison group (patients not exposed to digital nudges), and outcomes (patient treatment, safety, and management). The structure of the review followed the principles of PRISMA (Preferred Reporting Items of Systematic Reviews and Meta-Analysis) [38]. Complementary resources that guided the structure were inspired by recently published systematic reviews [12-13, 25-27, 33, 39-40]. For this systematic review, Scopus, PubMed, ACM Digital Library, Web of Science, and IEEE Xplore were searched. We defined inclusion and exclusion criteria that did not depend on any particular research field to receive a high variety of papers

and to see potential differences or similarities regarding operationalization and definitions of digital nudges. We included papers covering research on children and papers covering mental health. Previous reviews [27, 33] only included papers referring to nudging or digital nudging. However, we decided on more robust and broader terms and included papers mentioning cognitive bias as well as behavioral economics in general. The included papers needed to explore behavior or attitude change in a healthcare setting. In addition, the included papers needed to mention the prevention or treatment of some kind of disease or illness for a specific patient group. We excluded papers covering acute illnesses. Finally, the included papers needed to test or observe the impact of prototypes or fully developed DHTs that were embedded with digital nudges.

Search Strategy

Searches in all included databases were performed on May 7th, 2025, and the search included papers that were published until the end of the year 2024. To capture relevant papers, three search strings were used: behavioral science keywords, digital applications keywords, and device keywords. These three search strings were combined and used as a main search strategy in all the included databases (see Fig. 1 below). The main search string included words with similar meanings or used interchangeably with digital nudging, digital applications, or digital devices. Through this search strategy, we found 3655 references after removing duplicates.

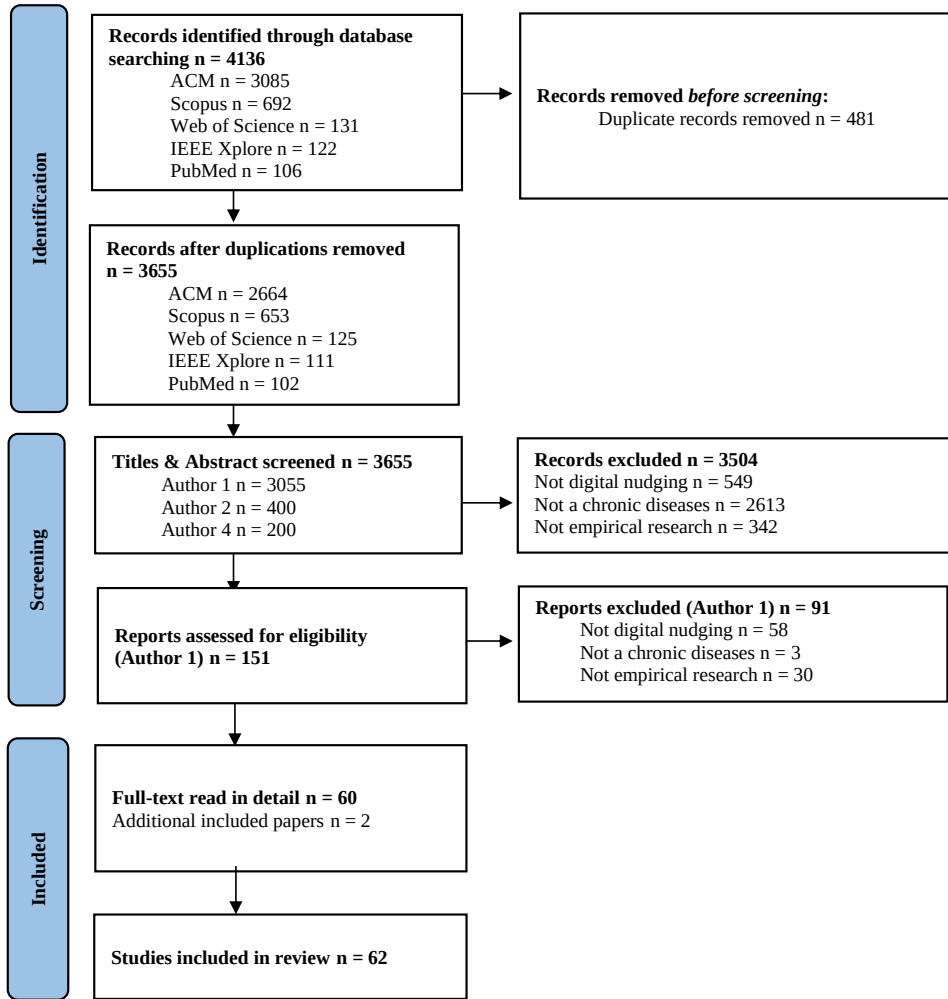
Fig. 1. Main search strategy.

"Nudge" OR "Nudging" OR "Digital nudging" OR "Cognitive bias" OR "Heuristics" OR "Dark patterns" OR "Behavioral economics" OR "Behavioural economics") AND ("Digital therapeutics" OR "Digital platform" OR "mHealth" OR "eHealth" OR "Remote care" OR "Digital health" OR "Self management" OR "Self monitoring" OR "Platform" OR "App") AND ("Self tracker" OR "Mobile application" OR "Smartphone" OR "Smart watch" OR "Smartwatch" OR "Wearable")

Selection and Data Collection Process

The selection process was conducted by the first, second, and fourth authors in three steps. We used the Zotero tool to manage the review process. In the first step, titles, abstracts, and keywords were screened applying the inclusion and exclusion criteria. We included papers with experimental studies where the effects of the interventions were studied either quantitatively or qualitatively. The interventions needed to be embedded into DHTs with the means of changing the behavior or attitudes of some patient groups. We excluded papers if there was no digital nudging applied, if there were no diseases or illnesses mentioned, and if there was no experimental study conducted. After the first selection process, 151 papers were included (see Figure 2 below). The second step involved in-depth reading of full texts, which resulted in further removing papers that were not considered digital nudging papers, mentioning diseases, or being experimental studies. After the second step, we were left with 60 papers that were considered eligible. During the synthesis of the results, two papers that had more recent research on the DHT already included in the search were added to the review. This resulted in a final selection of 62 papers.

Fig. 2. Selection process and inclusion.



Coding

The first, second, and fourth authors extracted different information from the primary publications. Firstly, we excerpted general information such as authors, titles, keywords, or the name of the journal. Then, the first author identified the year, context, country, and dependent variable of the study. Next, the first author looked for the delivery channel of the digital nudge, the nudge category, the context within healthcare, the data collection method, the duration of intervention, the number of participants, the number of case studies, the outcome, and the significance. All data were systematically stored in a spreadsheet and analyzed accordingly.

Analysis Procedure and Synthesis of Results

First, to structure and synthesize the findings, we created a morphological box to classify the dimensions and characteristics of the papers [27, 33, 41-42]. This was done to gain an understanding of the main characteristics of DHTs that were embedded with digital nudges. Second, the first author used the spreadsheet, which was the product of the coding process, to perform a thematic and qualitative analysis of the papers. The approach was based on healthcare settings to explore where DHTs embedded with digital nudges have been researched in practice. Finally, we compared the outcomes and significance of the studies to reflect on the effectiveness of DHTs, including digital nudges.

Results

How are digital nudges used in DHT?

In this systematic review, we cover 62 papers that include 96 experimental studies that tested or observed single or combinations of 119 nudging scenarios. 63% of the digital nudging interventions were delivered only through smartphone applications. In addition, 27% of the interventions were delivered using smartphone applications accompanied by smartwatches. In most cases, smartwatches were used to measure physical activity such as steps [46, 56, 49], but also heart rate [57, 85], or other behaviors such as smoking [69]. Other combinations with smartphone applications included smart scales to measure weight or body composition [49-50], or inhalers equipped with sensors [53, 84]. Interventions that did not include smartphone applications relied on SMS messages [54], VR glasses [71], robots [81], audio devices with physical artifacts [78], or digital platforms [80, 88].

The approaches of choice architecture can be broken down into several categories [42]. In our review, we relied on the existing framework for classifying nudges [33, 109-110]. Most of the papers (65%) studied digital intervention using combinations of nudging techniques. Feedback nudges are the most common, which include reminders and messages, sharing past and current behavior of patients, which have proven to be useful in health settings [39]. Next, there was an almost equal number of priming nudges, social reference nudges, and precommitment nudges. Following that were disclosure nudges [51] and warning nudges [65].

Most studies rely on field studies (84%) where the digital product or a prototype was tested on patients or volunteers. Patients with obesity [46-48], smoking addiction [68-71], alcoholism [62-67], heart conditions [56-58, 74-76, 85], at risk pregnant women [59-60], children with asthma [84], or diabetes [86]. In some cases, caregivers [84] were part of the field study or in other cases healthcare professionals also participated [53]. The lab studies mainly consisted of a single session where participants would test the product in a setting where the designers could observe and conduct semi-structured interviews [55, 61, 77, 83, 91]. One study was a statistical retrospective study on medical health records [45]. In many cases, data collection also relied on surveys and questionnaires throughout the studies [51, 56, 92]. The studies varied between a single session and 18 months, where the average length of interventions (excluding the single sessions) was three months and five days for a digital nudging intervention.

The summarized results of the dimensions and characteristics are presented in the morphological box in Fig. 3. It is based on the following dimensions: Main delivery channel, category, data collection, duration of intervention, medical context, outcome, and significance. The results from the medical context, outcome, and significance are presented in more detail in the following section.

Fig. 3: Morphological box of empirical nudging studies. The number in brackets indicates the number of papers in each box, except for the dimension “Category” where the number refers to the number of nudging approaches.

Dimension	Characteristics								
Main delivery channel (62)	Smartphone application (39)		Smartphone app & smartwatch (13)		Smartphone app & another device (4)		Digital platform (2)		Other digital setting (4)
Category (119)	Feedback (29)	Priming (22)	Social reference (22)	Precommitment (18)	Disclosure (11)	Simplification (8)	Loss aversion (5)	Warnings (3)	Default (1)
Data Collection (62)	Lab study (11)			Field study (50)			Other study (1)		
Duration (59)	Single session (14)			1-6 weeks (22)			2-months or longer (23)		
Context (62)	Metabolic & physical activity (13)		Adherence (10)	Addiction (10)	Rehabilitation (8)	Mental Health (11)		Children (8)	Other application (2)
Outcome (62)	Behavioural (29)			Attitudinal (26)			Multi-level (7)		
Significance (37)	Insignificant effect (6)					Significant effect (31)			

Applications and Effectiveness of digital nudges in DHTs for healthcare settings

The six themes, based on different application contexts in healthcare settings, are the first authors’ representation. The logic behind the themes was to focus on common aspects beyond the boundaries of certain medical specialties to gain an understanding of how DHTs embedded with digital nudging were applied in practice. The themes are metabolic and physical activity, adherence to treatment, addiction diseases, rehabilitation, mental health, and children’s health (see Fig. 4 below). Two of the papers did not fall into any of the themes in healthcare settings. They covered the prevention of sexually transmitted diseases [91] and infection control, considering the learnings of COVID-19 [92]. Half of the papers used the term *digital nudging* or referenced digital nudging studies in their research (31/62). The other papers used terms such as *cognitive bias modification*, *behavior change*, *behavioral economics*, *gamification*, and *educational or social influence* (31/62).

To reflect on the outcomes of the studies, we used an abstract level and looked at whether the objective was centered on changes in behavior or attitude. When studies investigate both higher-level outcomes and incorporate other levels, such as physiological outcomes, we coded them as multi-level. The heat map in Fig. 5 shows that digital nudges are almost equally used to change behavioral outcomes as well as attitudes. The significance was split up into statistically significant and statistically insignificant effects. Only 37 out of 62 papers reported results that were either significant or insignificant compared to a control group or baseline measures. 31 out of the 37 papers showed significantly positive results from the digital nudging interventions that were applied to the DHTs. The 25 papers that did not report any significant results were research papers focusing on the qualitative aspects of the DHTs.

Fig. 4: Category-context matrix of the number of digital nudging examples.

	Metabolic	Adherence	Addiction	Rehabilitation	Mental Health	Children	Other	Total
Feedback	8	6	1	6	4	4	-	29
Priming	3	1	9	3	3	1	2	22
Social reference	4	2	4	4	4	3	1	22
Precommitment	7	3	4	1	1	2	-	18
Disclosure	2	3	1	1	2	1	1	11
Simplification	-	3	-	2	2	1	-	8
Loss aversion	1	1	-	-	1	2	-	5
Warnings	-	-	2	1	-	-	-	3
Default	1	-	-	-	-	-	-	1
Framing	-	-	-	-	-	-	-	0
Total	26	19	21	18	17	14	4	119

Fig. 5: Outcome-context matrix of the number of digital nudging papers.

	Metabolic	Adherence	Addiction	Rehabilitation	Mental Health	Children	Other	Total
Behavioral	8	5	6	-	4	4	1	28
Attitudinal	5	4	2	5	6	3	1	26
Multi-level	-	1	1	3	1	2	-	8
Total	13	10	9	8	11	9	2	62

Metabolic and Physical Activity

Nudging methods such as feedback, reminders, and precommitment successfully altered patients' behavior towards more exercise, a healthier diet, and weight loss [43-51, 114-117]. See details in Table 2 below. Also, the support and social reference of forming two-person teams with a family member or friend resulted in significant weight loss for obese patients [49]. Feedback through smartphone applications in combination with smartwatches was, for example, successful in encouraging patients with peripheral artery diseases to get more exercise [51]. Even though these DHTs were in many cases successful in nudging patients towards more exercise, one study showed that regular reminders and feedback nudges can negatively impact the pleasure of performing the daily exercise tasks [93].

Treatment Adherence

Applying digital nudges such as simplification, disclosure, feedback, and precommitment into DHTs positively impacted the adherence to treatment for patients diagnosed with asthma [52-53], diabetes [54-55], heart diseases [56-58], and at-risk pregnancies [59-61]. See details in Table 2 below. Results showed that in some cases, younger people may be more likely to improve treatment adherence as they have a higher probability of being non-adherent [52]. Combining applications and sensors has the potential to simplify and improve all documentation during treatments, both for patients and healthcare professionals. An example of a successful intervention was an app providing reminders, visualized medication use, and motivational messages in combination with a sensor attached to a patient's asthma inhaler, allowing the uploading of medication use [53]. Another study explored the attitude towards nudging healthcare professionals toward the prescription of guideline-directed medical therapy for heart failure [58]. On one hand, the patients could easily enter their daily blood pressure, pulse, and weight manually into an app. On the other hand, healthcare professionals could visualize the data together with lab results, such as potassium and creatinine, making it easy to discuss the progress during clinical visits [58]. Furthermore, social reference nudges positively impacted treatment adherence where patients shared their weekly progress with a supportive sponsor and gained/lost points depending on their progress [56], and nudging through the sharing of information and educational material resulted in changes in the behavior and attitudes of patients [54-55]. Finally, two studies showed that patients wanted the freedom to choose the timing and content of the feedback nudges as they believed it would increase the probability of successful change [61] and enable more personalized behavior changes [57].

Addiction Disease

The application of cognitive bias modification into DHTs was successful in many cases for the reduction of alcohol consumption [62-67] and smoking [67-71]. See details in Table 2 below. Typical examples of priming with cognitive bias re-training or approach-avoidance training were training sessions where several pictures, either of alcoholic beverages or of non-alcoholic beverages, were presented consecutively in random order. Alcoholic beverages were swiped upward (away from the body), whereas non-alcoholic beverages were swiped downward (toward the body) [65]. For the treatment of smoking addiction, similar approaches were used for cognitive bias modification using apps [70], while other field studies used virtual reality glasses for the priming of the users [66]. Other approaches to smoking cessation included gamification, intending to educate users on the harmfulness of smoking [69] and sensors in smartwatches that detected smoking episodes from hand and arm gestures, making it effortless to share data with healthcare professionals about the timing, frequency, and location of smoking activities [68]. Finally, the combination of precommitment, self-monitoring, feedback messages, and cognitive bias retraining was successful in reducing alcohol consumption by increasing and higher-risk drinkers [62-64].

Rehabilitation

Nudging with social reference and digital group therapy were prominent methods in the context of rehabilitation after breast cancer [72-73], rehabilitation after heart surgery [74-76, 118], or traumatic injury [77, 119]. See details in Table 2 below. The DHTs were designed to allow patients to communicate, share experiences, and provide advice on coping strategies [72-73]. In an application for breast cancer survivors, some women found peer support comforting and reassuring, while others said they were not brave enough to post something [73]. For patients recovering from heart surgery, the ease and convenience of being able to pursue rehabilitation from the comfort of their home or work while being remotely monitored by caregivers at the rehabilitation center was highlighted [74-75].

Mental Health

Digital nudging interventions using feedback, priming, and social reference proved somewhat successful in supporting patients dealing with stress, anxiety, lack of psychological well-being, and problematic smartphone use [78-81, 120-124], and those diagnosed with mental health disorders [82-83]. The changes in attitude were measured with various standardized assessment tools. See details in Table 2. Some of the interventions ventured beyond the usage of mobile applications. An example was a handheld shape-changing biofeedback-based device to improve psychological well-being and reduce stress [78]. The users could synchronously feel their breath via kinesthetic haptic feedback to improve engagement and effectiveness of an audio-guided intervention [78]. Another example was a robotic companion that significantly improved psychological well-being [81]. Precommitment, self-assessment, setting personalized treatment plans, and reminders showed promise in the context of obsessive-compulsive disorder [82]. Finally, a study showed insignificant results for the impact of loss aversion nudges on the mental health and wellness of patients [83].

Children

Only two studies out of seven showed significant results when working with children and their adherence to treatment for asthma [84], heart disease [85], diabetes [86], or mental health issues [87-89, 125]. See details in Table 2 below. Digital nudging, with daily reminders, showed significant improvements in adherence to children's asthma treatment [84]. Social comparison methods between children dealing with problematic smartphone use also proved significant in changing children's behavior [90]. However, measurements from smartwatches showed that children with congenital heart diseases did not exercise more after receiving daily app messages [85], and feedback nudges in combination with loss aversion interventions were not significant in encouraging children with diabetes to do more exercise [86]. Even though the impact of the intervention was not measured explicitly, a DHT that supported collaboration in creating tasks, gaining points, and redeeming rewards showed promise for children with ADHD [87]. Furthermore, digital group therapy gave children with social anxiety and depression a sense of belonging and identification with the group, which led to feelings of security, stimulated positive thoughts, accountability, and a focus on individual strengths [88, 89].

Table 2. Effectiveness of digital nudges in DHTs by healthcare settings.

	#	Objective	Nudging category	Outcome	Signifi	Effect	p-value
Metabolic and physical act.	43	Motivate people to log diet	Feedback, reminders	Attitudinal			
	44	Increase step count	Feedback, precommitment	Attitudinal	Insign.		
	45	Weight loss	Precommitment, feedback	Behavioural	Yes	-3.74 kg	0.002
	46	Weight loss	Disclosure, feedback, precommitment, default	Behavioural	Yes	-1.7 kg	< 0.001
	47	Weight loss	Priming	Behavioural	Yes	-0.74 kg	0.03
	48	Increase step count	Social reference, precommitment	Behavioural	Yes	920 steps	< 0.001
	49	Weight loss	Social reference, precommitment	Behavioural	Yes	-4.8 lbs	< 0.001
	50	Motivate people to log diet	Loss aversion	Behavioural	Yes	$\gamma^2 = 3.991$	< 0.05
	51	Education and diseases man.	Disclosure, feedback	Attitudinal			
	114	Virtual pet to motivate exercise	Precommitment, social reference, feedback	Attitudinal			
	115	Wearable to motive exercise	Feedback, social reference, precommitment	Attitudinal			
	116	Motivate people to eat healthier	Feedback, priming	Behavioural	Yes	overeating -0.32	<0.001
Treatment adherence	117	View less images of food	Feedback, priming	Behavioural	Yes	exposure $\gamma^2=9.55$	0.008
	52	Asthma medication	Feedback	Behavioural			
	53	Asthma medication	Feedback, simplification	Behavioural	Yes	50.2% improvem.	0.01
	54	Diabetes educ. & weight loss	Precommitment, simplification, disclosure	Multi-level	Yes	-2.64 lbs	< 0.05
	55	Diabetes education	Disclosure, feedback	Attitudinal			
	56	Walking with heart disease	Precommitm., loss aversion, feedback, social ref.	Behavioural	Yes	868 steps	<0.0001
	57	Measure blood pressure	Feedback	Behavioural	Yes	14.40%	<0.001
	58	Guidelines for heart failure	Simplification, feedback	Attitudinal			
	59	Postpartum exercise	Social reference, precommitment	Behavioural	Yes	647 steps	<0.009
	60	Oral health during pregnancy	Disclosure	Attitudinal			
	61	Heart risk pregnancy education	Priming	Attitudinal			
Addiction disease	62	Usability of a drink-less app	Precommitment, social reference, priming	Attitudinal			
	63	Engagement with drink-less app	Precommitment, social reference, priming	Behavioural	Yes	odds ratio 1.02	<0.001
	64	Alcohol reduction	Precommitment, social reference, priming	Behavioural	Yes	-2 drinks w	0.026
	65	Alcohol reduction	Priming	Multi-level	Yes	-7.8 drinks w	<0.001
	66	Alcohol reduction	Priming	Behavioural	Yes	-8.1 drinks w	<0.001
	67	Alcohol craving reduction	Priming, feedback	Attitudinal	Yes	-2.83 PACS*	0.003
	68	Smoking cessation	Social reference, priming	Multi-level			
	69	Smoking cessation	Disclosure, precommitment	Behavioural	Insign.		
	70	Smoking cessation	Priming, warnings	Behavioural	Yes	-2.3	0.001
	71	Smoking cessation	Priming, warnings	Behavioural	Yes	-50%	0.004
Rehabilitation	72	Ph.activity post breast cancer	Social, commitment, warning, feedback, priming	Attitudinal			
	73	Adjuvant endocrine therapy	Social, disclosure, feedback	Attitudinal			
	74	Cardiac rehabilitation	Simplification, feedback	Multi-level			
	75	Cardiac rehabilitation	Simplification, feedback	Multi-level	Yes	-1.5 mg/dL*	0.01
	76	Cardiac rehabilitation	Social	Attitudinal			
	77	Brain injury rehabilitation	Priming	Attitudinal			
	118	Cardiac rehabilitation	Feedback, priming	Attitudinal			
	119	Post-traumatic stress disorder	Social reference, feedback	Behavioural			
Mental Health	78	Well-being intervention	Priming	Attitudinal			
	79	Reduce stress	Priming	Attitudinal	Yes	Anxiety score	0.012
	80	Reduce stress	Feedback	Attitudinal	Yes	DASS-21*	<0.05
	81	Well-being intervention	Social	Attitudinal	Yes	PHQ-9*	0.03
	82	Usability for OCD app	Social reference, feedback, precommitment	Attitudinal			
	83	Well-being intervention	Feedback, priming, loss aversion	Attitudinal	Insign.		
	120	Reduce stress	Feedback, disclosure	Multi-level	Yes	PSS-10	0.01
	121	Problematic smartphone use	Feedback	Behavioural	Insign.		
	122	Problematic smartphone use	Feedback	Behavioural	Yes	App use decrease	0.0005
	123	Problematic smartphone use	Simplification, disclosure	Behavioural	Yes	Social media use	<0.001
	124	Problematic smartphone use	Simplification	Behavioural	Yes	App use decrease	0.0001
Children	84	Asthma inhaler adherence	Feedback	Behavioural	Yes	47% improvem.	<0.001
	85	Increase physical activity	Feedback	Multi-level	Insign.		
	86	Diabetes adherence	Feedback, loss aversion	Attitudinal			
	87	Managing ADHD	Priming, precommitment	Attitudinal			
	88	Manag. 1st-episode psychosis	Social reference	Attitudinal			
	89	Reduce social anxiety	Social reference, disclosure, precommitment	Behavioural	Insign.		
	90	Problematic smartphone use	Social reference, simplification	Behavioural	Yes	Cohen d= -0.32	0.008
	125	Manage anxiety disorder	Loss aversion, feedback, social reference				
Orth.	91	Educ. about sexually transm.d.	Priming, disclosure, social reference	Attitudinal			
	92	Social distance in pandemic	Priming	Behavioural	Yes	HAM-A -5.64	0.01

* PACS = Penn Alcohol Consumption Scale. mg/dL = glycated hemoglobin. DASS-21 = Depression Anxiety and Stress Scale 21. PHQ-9 = Patient Health Questionnaire-9

Discussion

This systematic literature review offers in-depth insights into the ways digital nudging can be utilized in DHTs. When it comes to the type of technology, smartphones or mobile applications were most common, either as standalone services or in combination with other sensor-based devices such as a smartwatch, scale, or an inhaler. The most common digital nudging methods applied in DHTs were: (i) feedback in the form of messages or notifications, (ii) priming nudges, (iii) social reference, and (iv) precommitment. Importantly, most DHTs reviewed used a combination of digital nudging techniques. The papers included were mostly based on field studies where the subjects were patients, caregivers, healthcare professionals, or workplace volunteers. The studies varied between a single session and 18 months, where the average length of interventions (excluding the single sessions) was three and a half months for a digital nudging intervention. The studies observed and tested changes in behavior or attitude, but both were equally present in the papers reviewed. Most papers predominantly relied on quantitative data. Only 37 out of 62 papers (60%) performed significant tests on the effectiveness of the digital nudging interventions and thereof 31 papers showed significantly positive results (84%).

Previous systematic reviews on digital nudging have studied digital nudges across contexts, including health, but not focused specifically on the health context. In those papers, the effectiveness of digital nudging is estimated to be 21% effective in changing behavior [33]. Another systematic review focused on the effectiveness of self-management of patients with chronic diseases [39]. However, due to not having enough quality papers in that review, no results on the effectiveness of the nudging intervention were derived. Another review focused on nudges that influence healthcare professionals toward giving treatment in line with treatment guidelines [40]. Due to these shortcomings, our paper focuses on the use of digital nudges, embedded in DHT, for health purposes. In this systematic review, we cover 56 digital health technologies that have incorporated digital nudges in their design. When the design incorporates a combination of nudges, it can be hard to distinguish what effect each type of nudge has on the main objective of the DHT. It is also difficult to explore if a combination of two types of nudges is more powerful than one. The effectiveness varies between healthcare settings.

Studies with digital nudging interventions embedded in DHTs reported statistically significant changes in behavior or attitude in most cases in the context of metabolic and physical activity, as well as in the management of addiction disease. Those are important results for healthcare managers and policymakers, as these DHTs could be implemented in parallel with more traditional methods, with scalable and readily available solutions for patients. In essence, the goal in this healthcare context is to support patients in adopting a healthier lifestyle with weight loss, more exercise, and letting go of bad habits such as smoking and excessive drinking. A healthier lifestyle can serve as a preventive measure because excess weight increases the risk of heart disease, diabetes, and cancer [106]. Exercise, such as moderate or high-intensity walking, is also known to be beneficial for patients with heart disease [107]. This goes to show that there is a real opportunity in the management of patients for the prevention and treatment of lifestyle-related diseases.

In terms of treatment adherence and mental health interventions, our review shows that digital nudges embedded into DHTs were in many cases successful in changing the behavior and attitudes of patients. These DHTs have the potential to simplify and improve all documentation during treatments, both for patients and healthcare professionals. Good documentation practices in healthcare are vital for several reasons. First, accurate documentation helps ensure continuity of care and provides a comprehensive record of a patient's condition, treatments, and responses, which can prevent errors and improve patient safety [111]. Second, proper documentation facilitates clear communication among healthcare team members and ensures that all members of the team are informed about a patient's status and care plan [112]. Third, detailed documentation allows for the evaluation of the quality of care delivered and helps in identifying gaps in care and areas for improvement, aiding in the development of better practices and protocols [113]. Finally, documentation contributes to data that can be used for research, policymaking, and education, ultimately leading to advancements in healthcare practices [113]. Furthermore, our review shows that DHTs can, in some cases, serve as companions for patients during physical and mental treatment. The social interaction typically observed in human-human interactions can also prove impactful for mental health during human interaction with computers and machines, according to the 'computers are social actors' paradigm [103]. The notion that digital nudges have the potential to significantly improve documentation, patients' safety, and remote monitoring is something for healthcare managers

and policymakers to seriously consider when developing strategies for physical and mental treatment and the management of patients whilst considering the fast growth of patients living with diseases which present large-scale challenges for the healthcare system. One possible pathway forward is to rely on the patient's participation in self-care to a larger extent.

In our review, we found very few examples of significant changes in the behavior or attitude of patients during rehabilitation after therapy and in interventions designed for children. There are ample opportunities, for example, in incorporating social support and reference nudges into the design of DHTs for rehabilitation. Sharing of similar experiences can help patients better understand their situation and make sense of their symptoms, triggers, and treatments [94-95]. For example, there is a new goal for 'normal' life for patients following cardiac surgery, and experience sharing can help patients reach that goal [96]. 'Normal' refers to a person's acceptance of their own health experience when they discover it to be close to what is experienced by others [97-98]. Previous studies with cardiac patients [99-100] found that patients normalize their new experiences during cardiac rehabilitation by interacting and sharing experiences with other patients. This echoes efforts by people with diabetes to validate personal experiences of their condition and determine whether these experiences were normal [101-102]. What is special about designing interventions for children is that parents or guardians instantly become part of the process. In an example of an unsuccessful intervention for children with heart disease needing to do regular exercise, the parents perhaps overprotected the children. However, there is a large gain as teenagers who exercise are more likely to become adults who exercise regularly [104]. Where digital nudging methods are effective, the designers need to be aware of the ethical implications when developing solutions for patients and, in particular, children [105, 108].

Limitations and Future Work

Our search strategy was wider than previously published papers, which only allowed papers that either mentioned nudge or nudging. Due to the broadness of our search strategy, we received papers that mentioned gamification or cognitive behavioral therapy, which we categorized as digital nudges. This could result in selecting papers that some might not consider to be digital nudging studies. In our search strategy, we focus on mobile applications, smartwatches, wearables, and other self-trackers. This means we could have missed out on studies focusing on personalized web pages, emails, or text messages. Our collection of papers illustrated statistically significant results in 31 papers, while only 6 papers reported insignificant effects. Perhaps papers with significant results regarding the effectiveness of digital nudges are more likely to be published, leading to an embedded bias. Lastly, the first author reviewed most of the titles and all the full texts, while the second and fourth authors were active in the first phase. Our study sheds light on several areas that can be important avenues for future research. Based on the identification of our main findings, we suggest that future work look specifically toward four main areas of interest: (1) qualitative studies on digital nudges within DHT, as the studies published to date are mostly quantitative; (2) digital nudges in DHTs targeting healthcare professionals; (3) ethics of digital nudging and its counterpart, dark patterns; (4) digital nudges in the context of rehabilitation and interventions aimed at children.

Conclusion

In our systematic review of the literature, we aimed to address the following research question: "*How can digital nudges be used within digital health technologies in healthcare settings to support patient treatment, safety, and management?*" First, digital nudges are successful in the treatment and management of lifestyle-related diseases. This systematic review shows that digital feedback nudges can significantly change the behavior and attitudes of patients needing to get more physical exercise or lose weight. However, our findings also show the importance of keeping in mind that those types of messages and notifications can lead to a decrease in intrinsic motivation, meaning that the person may get less joy from performing those tasks. Furthermore, cognitive bias retraining or priming were effective methods in DHTs tackling addiction diseases. Second, digital nudges have a significant impact on adherence to treatment and improvements in mental health. Advances in technologies that rely on sensors and other similar wearable or nearable sensor-based devices simplify the process of sharing information regarding treatments, both from patients and healthcare professionals, leading to improved treatment adherence. Our findings also show that there is a range of creative ways to inform and educate patients, from relying on novel use of gamification elements to television-based drama about diabetes. Furthermore, biofeedback and social support from robots seem promising in the context

of mental health. Commitment and goal setting are also impactful, for example, for the treatment of obsessive-compulsive disorder. Third, there are opportunities for further research and development regarding digital nudging for rehabilitation and interventions aimed at children. Social support and shared experience play a vast role in motivating people to seek and complete rehabilitation programs. Additionally, the ease and convenience of being able to take part in such programs at home or work while being monitored by healthcare professionals remotely has proven to have a high impact [74]. This systematic review shows that motivating children is a difficult challenge, and the digital nudges in DHTs were unsuccessful in most cases. There may be ample gain from changing the behavior of children as they are young and have their lives ahead of them. Their age and undeveloped social skills are also a concern for the ethical aspects of digital nudging, and that is why it is important to design methods alongside and with parents and caregivers, allowing them to take an active part in the design process. Finally, our paper shows that there is a need to carefully consider the digital nudges embedded into DHTs, as digital nudging is powerful but should be used carefully.

References

- [1] Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., ... & Turner, M. B. (2016). Heart disease and stroke statistics—2016 update: a report from the American Heart Association. *circulation*, 133(4), e38-e360.
- [2] Ligibel, J. A., Bohlke, K., May, A. M., Clinton, S. K., Demark-Wahnefried, W., Gilchrist, S. C., ... & Alfano, C. M. (2022). Exercise, diet, and weight management during cancer treatment: ASCO guideline. *Journal of Clinical Oncology*, 40(22), 2491-2507.
- [3] American Diabetes Association. (2020). 5. Facilitating behavior change and well-being to improve health outcomes: Standards of Medical Care in Diabetes—2020. *Diabetes care*, 43(Supplement_1), S48-S65.
- [4] Wadden, T. A., Tronieri, J. S., & Butryn, M. L. (2020). Lifestyle modification approaches for the treatment of obesity in adults. *American psychologist*, 75(2), 235.
- [5] Ferrante, G., Licari, A., Marseglia, G. L., & La Grutta, S. (2021). Digital health interventions in children with asthma. *Clinical & Experimental Allergy*, 51(2), 212-220.
- [6] Ntoumanis, N., Ng, J. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., ... & Williams, G. C. (2021). A meta-analysis of self-determination theory-informed intervention studies in the health domain: Effects on motivation, health behavior, physical, and psychological health. *Health psychology review*, 15(2), 214-244.
- [7] Islind, A. S., Vallo Hult, H., Johansson, V., Angenete, E., & Gellerstedt, M. (2021). Invisible work meets visible work: infrastructuring from the perspective of patients and healthcare professionals. In *54th Hawaii International Conference on System Sciences (HICSS9, Tuesday, January 5, 2021 to Friday, January 8, 2021)* (pp. 3556-3565). Hawaii International Conference on System Sciences.
- [8] Thaler RH, Sunstein CR (2008) *Nudge: improving decisions about health, wealth, and happiness*. Yale University Press, New Haven
- [9] Schneider, C., Weinmann, M., & Vom Brocke, J. (2018). Digital nudging: guiding online user choices through interface design. *Communications of the ACM*, 61(7), 67-73
- [10] Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *science*, 185(4157), 1124-1131.
- [11] Kahneman, D., Lovallo, D., & Sibony, O. (2011). Before you make that big decision. *Harvard business review*, 89(6), 50-60
- [12] Ledderer, L., Kjær, M., Madsen, E. K., Busch, J., & Fage-Butler, A. (2020). Nudging in public health lifestyle interventions: a systematic literature review and metasynthesis. *Health Education & Behavior*, 47(5), 749-764.
- [13] Johansson, V., Islind, A. S., Lindroth, T., Angenete, E., & Gellerstedt, M. (2021). Online communities as a driver for patient empowerment: Systematic review. *Journal of medical Internet research*, 23(2), e19910.
- [14] Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. *Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017)*, 634-648.
- [15] Marteau, T. M., Ogilvie, D., Roland, M., Suhrcke, M., & Kelly, M. P. (2011). Judging nudging: can nudging improve population health?. *Bmj*, 342.
- [16] Saghai, Y. (2013). Salvaging the concept of nudge. *Journal of medical ethics*, 39(8), 487-493.
- [17] Vallgård, S. (2012). Nudge—A new and better way to improve health?. *Health policy*, 104(2), 200-203.

- [18] Skov, L. R., Lourenco, S., Hansen, G. L., Mikkelsen, B. E., & Schofield, C. (2013). Choice architecture as a means to change eating behaviour in self-service settings: a systematic review. *Obesity Reviews*, 14(3), 187-196.
- [19] Arno, A., & Thomas, S. (2016). The efficacy of nudge theory strategies in influencing adult dietary behaviour: a systematic review and meta-analysis. *BMC public health*, 16(1), 1-11.
- [20] Adam, A., & Jensen, J. D. (2016). What is the effectiveness of obesity related interventions at retail grocery stores and supermarkets?—a systematic review. *BMC public health*, 16(1), 1-18.
- [21] Bucher, T., Collins, C., Rollo, M. E., McCaffrey, T. A., De Vlieger, N., Van der Bend, D., ... & Perez-Cueto, F. J. (2016). Nudging consumers towards healthier choices: a systematic review of positional influences on food choice. *British Journal of Nutrition*, 115(12), 2252-2263.
- [22] Wilson, A. L., Buckley, E., Buckley, J. D., & Bogomolova, S. (2016). Nudging healthier food and beverage choices through salience and priming. Evidence from a systematic review. *Food Quality and Preference*, 51, 47-64.
- [23] Lycett, K., Miller, A., Knox, A., Dunn, S., Kerr, J. A., Sung, V., & Wake, M. (2017). 'Nudge' interventions for improving children's dietary behaviors in the home: A systematic review. *Obesity Medicine*, 7, 21-33.
- [24] Cadario, R., & Chandon, P. (2020). Which healthy eating nudges work best? A meta-analysis of field experiments. *Marketing Science*, 39(3), 465-486.
- [25] Whitehead, L., & Seaton, P. (2016). The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. *Journal of medical Internet research*, 18(5), e97.
- [26] Caraban, A., Karapanos, E., Gonçalves, D., & Campos, P. (2019, May). 23 ways to nudge: A review of technology-mediated nudging in human-computer interaction. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 1-15).
- [27] Bergram, K., Djokovic, M., Bezençon, V., & Holzer, A. (2022, April). The digital landscape of nudging: A systematic literature review of empirical research on digital nudges. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).
- [28] Hoffmann, C., & Thommes, K. (2020). Can digital feedback increase employee performance and energy efficiency in firms? Evidence from a field experiment. *Journal of Economic Behavior & Organization*, 180, 49-65.
- [29] Valdez, A. C., Ziefle, M., & Sedlmair, M. (2017). Priming and anchoring effects in visualization. *IEEE transactions on visualization and computer graphics*, 24(1), 584-594.
- [30] Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A room with a viewpoint: Using social norms to motivate environmental conservation in hotels. *Journal of consumer Research*, 35(3), 472-482.
- [31] Schwartz, J., Mochon, D., Wyper, L., Maroba, J., Patel, D., & Ariely, D. (2014). Healthier by precommitment. *Psychological science*, 25(2), 538-546.
- [32] Carmichael, L., Poirier, S. M., Coursaris, C. K., Léger, P. M., & Sénécal, S. (2022). Users' information disclosure behaviors during interactions with Chatbots: The effect of information disclosure nudges. *Applied Sciences*, 12(24), 12660.
- [33] Hummel, D., & Maedche, A. (2019). How effective is nudging? A quantitative review on the effect sizes and limits of empirical nudging studies. *Journal of Behavioral and Experimental Economics*, 80, 47-58.
- [34] Schmidt, U., & Zank, H. (2005). What is loss aversion?. *Journal of risk and uncertainty*, 30, 157-167.

- [35] Hall, M. G., Marteau, T. M., Sunstein, C. R., Ribisl, K. M., Noar, S. M., Orlan, E. N., & Brewer, N. T. (2018). Public support for pictorial warnings on cigarette packs: an experimental study of US smokers. *Journal of behavioral medicine*, 41, 398-405.
- [36] Jachimowicz, J. M., Duncan, S., Weber, E. U., & Johnson, E. J. (2019). When and why defaults influence decisions: A meta-analysis of default effects. *Behavioural Public Policy*, 3(2), 159-186.
- [37] Eriksen, M. B., & Frandsen, T. F. (2018). The impact of patient, intervention, comparison, outcome (PICO) as a search strategy tool on literature search quality: a systematic review. *Journal of the Medical Library Association: JMLA*, 106(4), 420.
- [38] Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of internal medicine*, 151(4), W-65.
- [39] Möllenkamp, M., Zeppernick, M., & Schreyögg, J. (2019). The effectiveness of nudges in improving the self-management of patients with chronic diseases: a systematic literature review. *Health Policy*, 123(12), 1199-1209.
- [40] Nwafor, O., Singh, R., Collier, C., DeLeon, D., Osborne, J., & DeYoung, J. (2021). Effectiveness of nudges as a tool to promote adherence to guidelines in healthcare and their organizational implications: a systematic review. *Social Science & Medicine*, 286, 114321.
- [41] Nickerson, R. C., Varshney, U., & Muntermann, J. (2013). A method for taxonomy development and its application in information systems. *European Journal of Information Systems*, 22, 336-359.
- [42] Sunstein, C. R. (2014). Nudging: a very short guide. *Journal of Consumer Policy*, 37, 583-588.
- [43] Kang, J., & Wei, L. (2020, May). Enter your dinner now! Uncovering persuasive message attributes in tracking reminders that motivate logging. In *Proceedings of the 14th EAI International Conference on Pervasive Computing Technologies for Healthcare* (pp. 122-132).
- [44] Cherubini, M., Villalobos-Zuñiga, G., Boldi, M. O., & Bonazzi, R. (2020). The unexpected downside of paying or sending messages to people to make them walk: Comparing tangible rewards and motivational messages to improve physical activity. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 27(2), 1-44.
- [45] Valinskas, S., Nakrys, M., Aleknavičius, K., Jonusas, J., & Lileikienė, A. (2023). User engagement and weight loss facilitated by a mobile app: retrospective review of medical records. *JMIR Formative Research*, 7(1), e42266.
- [46] Hu, E. A., Nguyen, V., Langheier, J., & Shurney, D. (2020). Weight reduction through a digital nutrition and food purchasing platform among users with obesity: longitudinal study. *Journal of medical Internet research*, 22(9), e19634.
- [47] Kakoschke, N., Hawker, C., Castine, B., de Courten, B., & Verdejo-Garcia, A. (2018). Smartphone-based cognitive bias modification training improves healthy food choice in obesity: A pilot study. *European Eating Disorders Review*, 26(5), 526-532.
- [48] Patel, M. S., Small, D. S., Harrison, J. D., Fortunato, M. P., Oon, A. L., Rareshide, C. A., ... & Hilbert, V. (2019). Effectiveness of behaviorally designed gamification interventions with social incentives for increasing physical activity among overweight and obese adults across the United States: the STEP UP randomized clinical trial. *JAMA internal medicine*, 179(12), 1624-1632.
- [49] Kurtzman, G. W., Day, S. C., Small, D. S., Lynch, M., Zhu, J., Wang, W., ... & Patel, M. S. (2018). Social incentives and gamification to promote weight loss: the LOSE IT randomized, controlled trial. *Journal of general internal medicine*, 33, 1669-1675.
- [50] Achananuparp, P., Lim, E. P., Abhishek, V., & Yun, T. (2018, April). Eat & tell: a randomized trial of random-loss incentive to increase dietary self-tracking compliance. In *Proceedings of the 2018 International Conference on Digital Health* (pp. 45-54).

- [51] Kim, M., Kim, Y., & Choi, M. (2022). Mobile health platform based on user-centered design to promote exercise for patients with peripheral artery disease. *BMC Medical Informatics and Decision Making*, 22(1), 206.
- [52] Zia, A., Brassart, A., Thomas, S., Ye, F., Stephenson, J. J., Mullins, C. D., & Jones, C. A. (2020). Patient-centric structural determinants of adherence rates among asthma populations: exploring the potential of patient activation and encouragement tool TRUSTR to improve adherence. *Journal of Health Economics and Outcomes Research*, 7(2), 111.
- [53] Rumi, G., Canonica, G. W., Foster, J. M., Chavannes, N. H., Valenti, G., Contiguglia, R., ... & Braidò, F. (2022). Digital coaching using smart inhaler technology to improve asthma management in patients with asthma in Italy: community-based study. *JMIR mHealth and uHealth*, 10(11), e25879.
- [54] Yin, Z., Lesser, J., Paiva, K. A., Zapata, J., Moreno-Vasquez, A., Grigsby, T. J., ... & Wang, J. Using Mobile Health Tools to Engage Rural Underserved Individuals in a Diabetes Education Program in South Texas: Feasibility Study. *JMIR Mhealth Uhealth*. 2020 Mar 24; 8 (3): e16683. 10.2196/16683.
- [55] Jiménez, A. S. A., Ramírez, N. A. B., Santana-Mancilla, P. C., Romero, J. C. M., & Acosta-Díaz, R. (2018, October). Heuristic Evaluation of a Gamified Application for Education in Patients with Diabetes. In *Proceedings of the 7th Mexican Conference on Human-Computer Interaction* (pp. 1-4).
- [56] Fanaroff, A. C., Patel, M. S., Chokshi, N., Coratti, S., Farraday, D., Norton, L., ... & Volpp, K. G. (2023). A randomized controlled trial of gamification, financial incentives, or both to increase physical activity among patients with elevated risk for cardiovascular disease: Rationale and design of the be active study. *American Heart Journal*, 260, 82-89.
- [57] Trinquart, L., Liu, C., McManus, D. D., Nowak, C., Lin, H., Spartano, N. L., ... & Murabito, J. M. (2023). Increasing Engagement in the Electronic Framingham Heart Study: Factorial Randomized Controlled Trial. *Journal of medical Internet research*, 25, e40784.
- [58] Hayashi, K., Hachiya, K., Yonezu, K., Otani, N., Furuya, K., Miura, I., ... & Uemura, N. (2023). A Heart Failure Smartphone Application That Nudges Patients/Physicians Toward Optimal Medical Therapy—Development and Usability Study—. *Circulation Reports*, 5(12), 459-462.
- [59] Lewey, J., Murphy, S., Zhang, D., Putt, M. E., Elovitz, M. A., & Riis, V. Effectiveness of a text-based gamification intervention to improve physical activity among postpartum individuals with hypertensive disorders of pregnancy: a randomized clinical trial. *JAMA Cardiol*. 2022; 7 (6): 591-599. *this study, postpartum individuals with heightened cardiovascular risk showed a notable increase in physical activity over, 12.*
- [60] Sarkar, C., Mohanty, V., Balappanavar, A. Y., Rijhwani, K., & Chahar, P. (2023). Development, Validation, and Usability Testing of Prototype Mobile Application for Oral Health Promotion during Pregnancy in India. *Indian Journal of Public Health*, 67(3), 376-381.
- [61] Smith, S. M., van der Kleij, R. M., Bais, B., Schermer, M. H., Ismaili M'hamdi, H., & Steegers-Theunissen, R. P. (2022). Preferences of women with a vulnerable health status towards nudging for adequate pregnancy preparation as investment in health of future generations: a qualitative study. *BMC Pregnancy and Childbirth*, 22(1), 559.
- [62] Crane, D., Garnett, C., Brown, J., West, R., & Michie, S. (2017). Factors influencing usability of a smartphone app to reduce excessive alcohol consumption: think aloud and interview studies. *Frontiers in public health*, 5, 240357.
- [63] Garnett, C., Perski, O., Tombor, I., West, R., Michie, S., & Brown, J. (2018). Predictors of engagement, response to follow up, and extent of alcohol reduction in users of a smartphone app (drink less): secondary analysis of a factorial randomized controlled trial. *JMIR mHealth and uHealth*, 6(12), e11175.
- [64] Oldham, M., Beard, E., Loebenberg, G., Dinu, L., Angus, C., Burton, R., ... & Garnett, C. (2024). Effectiveness of a smartphone app (Drink Less) versus usual digital care for reducing alcohol consumption among increasing-and-higher-risk adult drinkers in the UK: a two-arm, parallel-group, double-blind, randomised controlled trial. *EClinicalMedicine*, 70.

- [65] Laurens, M. C., Pieterse, M. E., Brusse-Keizer, M., Saleminck, E., Ben Allouch, S., Bohlmeijer, E. T., & Postel, M. G. (2020). Alcohol avoidance training as a mobile app for problem drinkers: longitudinal feasibility study. *JMIR mHealth and uHealth*, 8(4), e16217.
- [66] Manning, V., Piercy, H., Garfield, J. B. B., Clark, S. G., Andrabi, M. N., & Lubman, D. I. (2021). A personalized approach bias modification smartphone app (“SWiPE”) to reduce alcohol use: open-label feasibility, acceptability, and preliminary effectiveness study. *JMIR mHealth and uHealth*, 9(12), e31353.
- [67] Peerenboom, N., Guzman, N. V., Kvamme, T., Ritou, V., Casero, V., & Voon, V. (2023). Developing digital interventions for a post-Covid world: A smartphone-based approach-avoidance training to reduce alcohol craving. *Scandinavian Journal of Psychology*.
- [68] White, J. S., Salem, M. K., Toussaert, S., Westmaas, J. L., Raiff, B. R., Crane, D., ... & Thrul, J. (2023). Developing a Game (Inner Dragon) Within a Leading Smartphone App for Smoking Cessation: Design and Feasibility Evaluation Study. *JMIR serious games*, 11(1), e46602.
- [69] Joyce, C. M., Saulsgiver, K., Mohanty, S., Bachiredy, C., Molfetta, C., Steffy, M., ... & Buttenheim, A. M. (2021). Remote patient monitoring and incentives to support smoking cessation among pregnant and postpartum medicaid members: three randomized controlled pilot studies. *JMIR Formative Research*, 5(9), e27801.
- [70] Machulska, A., Eiler, T. J., Haßler, B., Kleinke, K., Brück, R., Jahn, K., ... & Klucken, T. (2023). Mobile phone-based approach bias retraining for smokers seeking abstinence: a randomized-controlled study. *International Journal of Mental Health and Addiction*, 1-22.
- [71] Machulska, A., Eiler, T. J., Kleinke, K., Grünewald, A., Brück, R., Jahn, K., ... & Klucken, T. (2021). Approach bias retraining through virtual reality in smokers willing to quit smoking: a randomized-controlled study. *Behaviour research and therapy*, 141, 103858.
- [72] Marcu, G., Misra, A., Caro, K., Plank, M., Leader, A., & Barsevick, A. (2018, May). Bounce: designing a physical activity intervention for breast cancer survivors. In *Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare* (pp. 25-34).
- [73] Brett, J., Boulton, M., & Watson, E. (2018). Development of an e-health app to support women prescribed adjuvant endocrine therapy after treatment for breast cancer. *Patient preference and adherence*, 2639-2647.
- [74] Sankaran, S., Frederix, I., Haesen, M., Dendale, P., Luyten, K., & Coninx, K. (2016, June). A grounded approach for applying behavior change techniques in mobile cardiac tele-rehabilitation. In *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments* (pp. 1-8).
- [75] Sankaran, S., Dendale, P., & Coninx, K. (2019). Evaluating the impact of the HeartHab app on motivation, physical activity, quality of life, and risk factors of coronary artery disease patients: multidisciplinary crossover study. *JMIR mHealth and uHealth*, 7(4), e10874.
- [76] Tadas, S., Dickson, J., & Coyle, D. (2023, April). Using Patient-Generated Data to Support Cardiac Rehabilitation and the Transition to Self-Care. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).
- [77] Rahmani-Katigari, M., Mohammadian, F., & Shahmoradi, L. (2023). Development of a serious game-based cognitive rehabilitation system for patients with brain injury. *BMC psychiatry*, 23(1), 893.
- [78] Farrall, A., Taylor, J., Ainsworth, B., & Alexander, J. (2023, April). Manifesting Breath: Empirical Evidence for the Integration of Shape-changing Biofeedback-based Artefacts within Digital Mental Health Interventions. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-14).
- [79] Blanco, I., Boemo, T., Martin-Garcia, O., Koster, E. H., De Raedt, R., & Sanchez-Lopez, A. (2023). Online Contingent Attention Training (OCAT): transfer effects to cognitive biases, rumination, and anxiety symptoms from two proof-of-principle studies. *Cognitive Research: Principles and Implications*, 8(1), 28.

- [80] Howe, E., Suh, J., Bin Morshed, M., McDuff, D., Rowan, K., Hernandez, J., ... & Czerwinski, M. P. (2022, April). Design of digital workplace stress-reduction intervention systems: Effects of intervention type and timing. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).
- [81] Jeong, S. (2023). Living With Robotic Companions for Better Psychological Well-Being. *XRDS: Crossroads, The ACM Magazine for Students*, 30(1), 32-37.
- [82] Rezaee, R., Parsa, Z., Ahmadzadeh, L., Ahmadian, L., Avazzadeh, S., & Marzaleh, M. A. (2023). Self-help application for obsessive-compulsive disorder based on exposure and response prevention technique with prototype design and usability evaluation: A cross-sectional study. *Health Science Reports*, 6(9), e1577.
- [83] Chang, C., Palermo, E., Deswert, S., Brown, A., & Nuske, H. J. (2023). Money can't buy happiness: A randomized controlled trial of a digital mental health app with versus without financial incentives. *Digital Health*, 9, 20552076231170693.
- [84] Kenyon, C. C., Sundar, K. G., Gruschow, S. M., Quarshie, W. O., Feudtner, C., Bryant-Stephens, T. C., & Miller, V. A. (2020). Tailored medication adherence incentives for high-risk children with asthma: a pilot study. *Journal of Asthma*, 57(12), 1372-1378.
- [85] Willinger, L., Oberhoffer-Fritz, R., Ewert, P., & Müller, J. (2023). Digital Health Nudging to increase physical activity in pediatric patients with congenital heart disease: a randomized controlled trial. *American Heart Journal*, 262, 1-9.
- [86] Krmpotic, K., Gallant, J. R., Zufelt, K., & Zuijdewijk, C. (2022). User-centred development of an mHealth app for youth with type 1 diabetes: the challenge of operationalizing desired features and feasibility of offering financial incentives. *Health and Technology*, 12(2), 499-513.
- [87] Silva, L. M., Cibrian, F. L., Monteiro, E., Bhattacharya, A., Beltran, J. A., Bonang, C., ... & Hayes, G. R. (2023, April). Unpacking the Lived Experiences of Smartwatch Mediated Self and Co-Regulation with ADHD Children. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-19).
- [88] Lederman, R., Wadley, G., Gleeson, J., Bendall, S., & Álvarez-Jiménez, M. (2014). Moderated online social therapy: Designing and evaluating technology for mental health. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 21(1), 1-26.
- [89] Biagianti, B., Conelea, C., Dabit, S., Ross, D., Beard, K. L., Harris, E., ... & Bernstein, G. A. (2023). A Mobile Application Adjunct to Augment Cognitive-Behavioral Group Therapy for Adolescents with Social Anxiety: Feasibility and Acceptability Results from the Wiring Adolescents with Social Anxiety via Behavioral Interventions Pilot Trial. *Journal of child and adolescent psychopharmacology*, 33(6), 212-224.
- [90] Hamamura, T., Kurokawa, M., Mishima, K., Konishi, T., Nagata, M., & Honjo, M. (2023). Standalone effects of focus mode and social comparison functions on problematic smartphone use among adolescents. *Addictive Behaviors*, 147, 107834.
- [91] Ruiz-López, T., Sen, S., Jakobsen, E., Tropé, A., Castle, P. E., Hansen, B. T., & Nygård, M. (2019). FightHPV: design and evaluation of a mobile game to raise awareness about human papillomavirus and nudge people to take action against cervical cancer. *JMIR serious games*, 7(2), e8540.
- [92] Ndulue, C., & Orji, R. (2021, March). Heuristic evaluation of an African-centric mobile persuasive game for promoting safety measures against COVID-19. In *Proceedings of the 3rd African Human-Computer Interaction Conference: Inclusiveness and Empowerment* (pp. 43-51).
- [93] Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, 55(1), 68.
- [94] Antypas, K., & Wangberg, S. C. (2014). Combining users' needs with health behavior models in designing an internet-and mobile-based intervention for physical activity in cardiac rehabilitation. *JMIR research protocols*, 3(1), e2725.

- [95] O’kane, A. A., Park, S. Y., Mentis, H., Blandford, A., & Chen, Y. (2016). Turning to peers: integrating understanding of the self, the condition, and others’ experiences in making sense of complex chronic conditions. *Computer Supported Cooperative Work (CSCW)*, 25, 477-501.
- [96] Tadas, S., Pretorius, C., Foster, E. J., Gorely, T., Leslie, S. J., & Coyle, D. (2021). Transitions in technology-mediated cardiac rehabilitation and self-management: qualitative study using the theoretical domains framework. *JMIR cardio*, 5(2), e30428.
- [97] Genuis, S. K. (2012). Constructing “sense” from evolving health information: A qualitative investigation of information seeking and sense making across sources. *Journal of the American Society for Information Science and Technology*, 63(8), 1553-1566.
- [98] Penrod, J., Hupcey, J. E., Shipley, P. Z., Loeb, S. J., & Baney, B. (2012). A model of caregiving through the end of life: seeking normal. *Western journal of nursing research*, 34(2), 174-193.
- [99] Tadas, S., & Coyle, D. (2020). Barriers to and facilitators of technology in cardiac rehabilitation and self-management: systematic qualitative grounded theory review. *Journal of medical Internet research*, 22(11), e18025.
- [100] Tadas, S., Pretorius, C., Foster, E. J., Gorely, T., Leslie, S. J., & Coyle, D. (2021). Transitions in technology-mediated cardiac rehabilitation and self-management: qualitative study using the theoretical domains framework. *JMIR cardio*, 5(2), e30428.
- [101] O’kane, A. A., Park, S. Y., Mentis, H., Blandford, A., & Chen, Y. (2016). Turning to peers: integrating understanding of the self, the condition, and others’ experiences in making sense of complex chronic conditions. *Computer Supported Cooperative Work (CSCW)*, 25, 477-501.
- [102] Webster, M., Foster, E., Comber, R., Bowen, S., Cheetham, T., & Balaam, M. (2015, June). Understanding the lived experience of adolescents with type 1 diabetes: opportunities for design. In *Proceedings of the 14th international conference on Interaction Design and Children* (pp. 140-149).
- [103] Nass, C., Steuer, J., & Tauber, E. R. (1994, April). Computers are social actors. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 72-78).
- [104] Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., & Raitakari, O. (2005). Physical activity from childhood to adulthood: a 21-year tracking study. *American journal of preventive medicine*, 28(3), 267-273.
- [105] Jóhannsdóttir, Duta-Visescu, I., L. G., Óskarsdóttir, M., Islind, A. S. (in-review). Two sides of Persuasive System Design: Understanding Digital Nudging and Dark Patterns and its Impact on Teenage Girls.
- [106] Burke, L. E., & Wang, J. (2011). Treatment strategies for overweight and obesity. *Journal of Nursing scholarship*, 43(4), 368-375.
- [107] Gerhard-Herman, M. D., Gornik, H. L., Barrett, C., Barshes, N. R., Corriere, M. A., Drachman, D. E., ... & Walsh, M. E. (2017). 2016 AHA/ACC guideline on the management of patients with lower extremity peripheral artery disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Journal of the American College of Cardiology*, 69(11), e71-e126.
- [108] Fogg, B. J. (2003). Persuasive technology: using computers to change what we think and do. *Ubiquity*, 2002(December), 2.
- [109] Münscher, R., Vetter, M., & Scheuerle, T. (2016). A review and taxonomy of choice architecture techniques. *Journal of Behavioral Decision Making*, 29(5), 511-524.
- [110] Johnson, E. J., Shu, S. B., Dellaert, B. G., Fox, C., Goldstein, D. G., Häubl, G., ... & Weber, E. U. (2012). Beyond nudges: Tools of a choice architecture. *Marketing letters*, 23, 487-504.

- [111] McCarthy, B., Fitzgerald, S., O'Shea, M., Condon, C., Hartnett-Collins, G., Clancy, M., ... & Savage, E. (2019). Electronic nursing documentation interventions to promote or improve patient safety and quality care: A systematic review. *Journal of nursing management*, 27(3), 491-501.
- [112] Asmirajanti, M., Hamid, A. Y. S., & Hariyati, R. T. S. (2019). Nursing care activities based on documentation. *BMC nursing*, 18, 1-5.
- [113] Pine, K. H., Landon, L. A., Bossen, C., & VanGelder, M. E. (2023). Innovations in clinical documentation integrity practice: Continual adaptation in a data-intensive healthcare organisation. *Health Information Management Journal*, 52(2), 119-124.
- [114] Khotchasing, K., Hoang, N. H., Saleh, A., & Liang, Z. (2024, October). WristPet: Promoting Daily Physical Activity Through Nudge Theory in a Smartwatch App. In *2024 IEEE 13th Global Conference on Consumer Electronics (GCCE)* (pp. 331-332). IEEE.
- [115] Asimakopoulos, G., Asimakopoulos, S., & Spillers, F. (2024). "It tracks me!": An analysis of apple watch nudging and user adoption mechanisms. *Health Informatics Journal*, 30(4), 14604582241291405.
- [116] Chew, H. S. J., Chew, N. W., Loong, S. S. E., Lim, S. L., Tam, W. S. W., Chin, Y. H., ... & Ngiam, K. Y. (2024). Effectiveness of an artificial intelligence-assisted app for improving eating behaviors: Mixed methods evaluation. *Journal of medical Internet research*, 26, e46036.
- [117] Choi, R., Park, S., Han, S., & Lee, S. J. (2024, May). FoodCensor: Promoting Mindful Digital Food Content Consumption for People with Eating Disorders. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (pp. 1-18).
- [118] Patterson, K., Keegan, R., Davey, R., & Freene, N. (2024). Implementing a sedentary behavior change smartphone app in cardiac rehabilitation: a qualitative analysis guided by the theoretical domains framework and capability, opportunity, and motivation-behavior model. *Journal of Cardiovascular Nursing*, 39(1), E12-E20.
- [119] Haque, M. R., Franco, Z., Madiraju, P., Baker, N. D., Ahamed, S. I., Winstead, O., ... & Rubya, S. (2024, May). " Butt call me once you get a chance to chat 😊": Designing Persuasive Reminders for Veterans to Facilitate Peer-Mentor Support. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (pp. 1-17).
- [120] Dietel, F. A., Rupprecht, R., Seriyó, A. M., Post, M., Sudhoff, B., Reichart, J., ... & Buhlmann, U. (2024). Efficacy of a smartphone-based Cognitive Bias Modification program for emotion regulation: A randomized-controlled crossover trial. *Internet Interventions*, 35, 100719.
- [121] Keller, J., Herrmann-Schwarz, T., Roitzheim, C., Mertens, L., Christin Brockmeier, L., & Kumar Purohit, A. (2024). A digital nudge-based intervention to interrupt Instagram usage: Randomized controlled pilot study. *European Journal of Health Psychology*.
- [122] Shahu, A., Pechstein, F., & Michahelles, F. (2024). Beyond Screen Time: Exploring Smartwatch Interventions for Digital Well-Being. In *Proceedings of Mensch und Computer 2024* (pp. 83-98).
- [123] Haliburton, L., Grüning, D. J., Riedel, F., Schmidt, A., & Terzimehić, N. (2024, May). A Longitudinal In-the-Wild Investigation of Design Frictions to Prevent Smartphone Overuse. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).
- [124] Lu, T., Zheng, H., Zhang, T., Xu, X. O., & Guo, A. (2024, May). InteractOut: leveraging interaction proxies as input manipulation strategies for reducing smartphone overuse. In *Proceedings of the 2024 CHI conference on human factors in computing systems* (pp. 1-19).
- [125] Bress, J. N., Falk, A., Schier, M. M., Jaywant, A., Moroney, E., Dargis, M., ... & Gunning, F. M. (2024). Efficacy of a Mobile App-Based Intervention for Young Adults With Anxiety Disorders: A Randomized Clinical Trial. *JAMA network open*, 7(8), e2428372-e2428372.

Appendix F

Two sides of Persuasive System Design: Understanding Digital Nudging and Dark Patterns and its Impact on Teenage Girls

Two sides of Persuasive System Design: Understanding Digital Nudging and Dark Patterns and its Impact on Teenage Girls

Lilja Guðrún Jóhannsdóttir – Reykjavík University – Iceland – liljaj20@ru.is

Ioana Visescu - Reykjavík University – Iceland – ioanad@ru.is

Marta Kristín Lárusdóttir – Reykjavík University – Iceland – marta@ru.is

María Óskarsdóttir – Reykjavík University – Iceland – mariaoskars@ru.is

Anna Sigríður Islind – Reykjavík University – Iceland – annasi@ru.is

Abstract

Persuasive system design (PSD) that guides individuals' decision-making in a digital environment can be a powerful tool that needs to be handled with responsibility. Vulnerable user groups, such as teenagers and young adults are proving more likely to be influenced by PSD. In light of that, we conducted a case study with 273 fourteen-year-old girls in Scandinavia to understand the recognition of teenage girls towards the two sides of PSD, namely digital nudging and dark patterns. Our findings show that the teenage girls had a hard time recognizing specific features of PSD. Based on our findings, we offer two main contributions. Firstly, we offer in-depth insights into the way teenage girls recognize PSDs. Secondly, we contribute with design guidelines for designers and educators for ethical nudge design.

Keywords: Digital nudging, dark patterns, digital responsibility, persuasive system design

1. Introduction

As humans, we face choices every day. Choice architecture refers to the way choices are presented, and the presentation itself can affect the decisions made by individuals following that presentation of choices (Thaler and Sunstein, 2008). The choice architecture is rarely neutral and most often includes a target for how the preferred choice is (Weinman et al., 2016). Influencing peoples' decision-making process with cues laid out within the choice architecture has recently been coined as nudging (Thaler and Sunstein, 2008). With the rise of technology that can hold *persuasive powers*, digital nudging has emerged in the literature (Schmitz et al., 2024). For the past few years, the interest in and understanding of digital nudging, specifically within the field of IS, has been maturing. Digital nudging outlines an approach where people's cognitive biases are actively used and applied to the design elements embedded within the user interface to affect the digital choice architecture presented to the users (Mirsch et al. 2017; Schneider et al. 2018). The purpose of nudges is to serve the users and aid them in making better decisions *as judged by themselves*. This is described by Thaler as libertarian paternalism, which is arguably what makes nudges ethically acceptable (Thaler and Sunstein, 2008). Nudging in general and digital nudging, in particular, is therefore intricately linked to upholding the person's freedom of choice while guiding them toward

a decision that is deemed fruitful for their own long-term goals or societal well-being, in an ethical manner and without removing options (Mettler and Stephanovic, 2023).

Persuasive System Design (PSD) is an approach to make technology capable of persuading users to change their behaviors or attitudes and is often defined as behavioral influence without using coercion or deception (Spahn, 2012). PSD is suggested to target the cognitive reflective system of the brain, while digital nudging way target the cognitive automatic system (Gram-Hansen, S. B., 2021). However, digital nudges are seen as ethical as they are based on social values, and they fall under the umbrella of PSD (Lembcke et al. 2020). The less ethical part of PSD, namely dark patterns, also falls under the umbrella of PSD but outlines the *dark side* of digital nudging as their motives are those of the designers of the information system, without preserving the freedom of choice for the users (Gray et al., 2018, Clausen et al., 2022). The intentions of the designer are sometimes unclear, making it hard to understand if the PSD should be categorized as digital nudges or dark patterns.

There is a need to pay serious attention to the way PSD, in general, and digital nudges and dark patterns, in particular, are understood by users, as the trends of utilizing PSD have been growing rapidly and are likely to continue to grow in the foreseeable future (Bergram et al., 2022). Consequently, this is an important research topic, especially as vulnerable user groups, such as teenagers and young adults, are proving more likely to be influenced by PSD, in comparison to grown-ups who may apply an increasingly critical filter to the use of PSD (Selnes, 2023). Furthermore, teenagers and young adults spend a considerable amount of their daily activities online (Rogers, 2019; Susser et al., 2019; Bristol & Mangleburg, 2005), which gives rise to increased exposure to and impact by PSD. When examining the topic further, girls are more likely to use the internet for schoolwork and social networking compared to boys (Stoilova et al., 2021) and have been shown to spend more time online on their smartphones (Smahel et al., 2020). Ethics should be considered a defining feature of PSD, and the targeting of vulnerable groups such as children should be considered unethical (Fogg, 2003). In cases of digital nudges and dark patterns, seemingly similar methods are often used but in different contexts, and distinguishing between those is vital. Due to the transformational power of PSDs in connection with vulnerable groups of users, such as teenage girls, their design and utilization calls for responsibility and care. The way choice architecture is presented has also been specifically linked to a greater impact on adolescents in general and girls in particular (Müller et al., 2016), outlining a specific area of interest in literature (Reiner et al., 2017; Cebollero-Salinas et al., 2022).

Consequently, the delicate nature of teenagers and young adults in general and teenage girls in particular is the focal point of this case study. The research problem that emerges here is whether teenage girls recognize PSD after receiving a lecture on those design methods. Accordingly, we formulate the following research question (RQ):

RQ1: How well do teenage girls recognize PSD after receiving a lecture on persuasive design methods?

This study aims to explore how teenage girls perceive and recognize PSD, including digital nudges and dark patterns, after being educated on these concepts, and to use these insights to inform ethical and responsible design and educational practices. We assess how factors such as presentation order, context, and prior exposure influence recognition and attitudes toward digital nudges and

dark patterns. We also highlight the importance of including vulnerable user groups, like teenage girls, in the design and discussion process, advocating for participatory design and critical digital education. To answer the research question above, we conducted a case study with 273 teenage girls. The main contribution is two-fold. Firstly, we contribute with insights that teenage girls have a hard time pinpointing features of PSDs. Secondly, we contribute with design guidelines for persuasive system design to be used by designers and educators.

2. Related work

2.1 Understanding nudges

Thaler and Sunstein coined the term *nudge* as an important element in the choice architecture (Thaler and Sunstein, 2008). Thaler received the Nobel Prize in Economics in 2017 for his research on nudges, pointing towards the significance of the work. If we examine the origin and meaning of nudging theory, which derives from behavioral economics, it acknowledges that individuals do not always make informed decisions about their health, welfare, and life in general (Thaler and Sunstein, 2008). Instead, people utilize shortcuts that help simplify the decision-making process. These shortcuts are referred to as heuristics or cognitive biases (Tversky and Kahneman, 1974). Because of the inherent link to cognitive biases, nudging has been illustrated as being heavily reliant on human cognition (Kahneman, 2003). Nudges are defined as intentional and targeted interventions to modify the choice architecture and alter an individual's behavior in the desired direction by taking advantage of cognitive biases (Cho and Bates, 2018). One of the most significant examples is when the default option of organ donation was changed from opt-in to opt-out, which nearly doubled the participation in organ donation (Johnson and Goldstein, 2003). Analysis reveals that 62% of empirical nudging studies are statistically significant (Hummel and Maedche, 2019). A systematic review and meta-analysis also reveal that nudges result in an average 15% increase in healthier dietary or nutritional choices, as measured by a change in frequency of health choices or change in overall caloric consumption (Arno and Thomas, 2016). Following the large-scale impact in physical settings, the development of digital nudging has grown as digital choice architecture increasingly influences peoples' lives (Lembcke et al., 2019). Digital nudging has been shown to have a significant impact on decision-making, and the effects in digital settings are comparable to traditional nudging (Zhang et al., 2015).

Designers can improve digital choices with digital nudging to support individuals in making beneficial decisions and enjoying an enhanced user experience, ultimately increasing user satisfaction (Mirsch, Lehrer, and Jung, 2018). Relying on heuristics and cognitive biases makes digital nudging a powerful tool for designers of digital choice environments because people are subconsciously influenced in their decisions. These persuasive user interface design elements are embedded elements in PSD and include graphic design, content, wording, and other small features such as user reviews, ratings, or push notifications on smartphones that remind the user to be more active (Weinmann et al., 2016). Designers are often not aware of their role in the design of PSD, or if they are aware of it, they lack a systematic approach to designing digital nudges. Therefore, digital choice environments are often designed by trial and error, where best practices are copied from competitors and often modified ineffectively to have an unintended influence on choice architecture, which ultimately impacts the decision-making of the users (Mirsch, Lehrer, and Jung, 2018). This can result in “mindlessness” when designing and implementing digital choice architectures (Salovaara et al., 2019). The answer to designing without a clear goal lies in the consideration of responsibility. Responsibility allows us to evaluate transformational digital

technologies and the use of PSD in a balanced manner, by factoring in both harmful and positive outcomes from the engagement with such artifacts (Voegtlin et al., 2022). A systematic approach to designing digital nudges, considering responsibility and ethics, should be the guiding light for designers when designing user interfaces, user experiences, choice architecture, and digital services in general. That brings us to the discussion on ethics in design and how it supports designers to positively leverage the transformational powers of digital technologies.

2.2 Ethics in Persuasive System Design

The importance of ethical consideration in persuasive design is often addressed in the persuasive technology community. Persuasion is generally understood as an ethical approach to behavior change, yet the ethical implications seem to be more recognized by academics rather than generally applied in persuasive technology (Kight & Gram-Hansen, 2019). The “golden rule” principle that “creators of a persuasive technology should never seek to persuade a person or persons of something they themselves would not consent to be persuaded to do” (Berdichevsky & Neuenschwander, 1999) is a common guideline for designers to follow. It is based on the perspective that ethics should be viewed through the motivation and methods of the designers, as the technologies are simply performing the methods developed by the designers, and technology itself is not capable of intent. Another viewpoint is that computers themselves are powerful persuaders because they represent in public opinion a kind of mathematical precision that may serve as a role model of ‘true and accurate’ feedback (Fogg, 2003). Studying moral and ethical principles, along with human rights, can move us beyond subjective individualism and allow us to define ethical principles as the “right and responsible action” (Atkinson, 2006). There have been developed design methods to support responsible PSD. The Value Sensitive Design was developed based on “human values” such as “privacy”, “autonomy”, and “moral beliefs of the technology” rather than usability (Davis, 2009). Another method is the Participatory Design, which allows the users to be part of the design process and “is very much concerned with social learning and multi-stakeholder negotiation” (Davis, 2009).

Spahn (2011) explores if guidelines for the field of persuasive technology can be grounded in the speech-act aspect. The speech-act theory expands the scope of the philosophical efforts to understand the ‘meaning of words’ beyond the strictly propositional aspects of language (Austin, 1962 and Searle, 1969). There are four implicit validity claims inherent in every speech-act (Habermas, 1993). Based on them, Spahn created four guidelines that are relevant for the usage and development of persuasive technology: (i) comprehensibility, (ii) truth, (iii) truthfulness, and (iv) appropriateness. *Comprehensibility* is the most basic precondition for communication and refers to the utterance of words being comprehensible. In the context of digital technology, that would translate to the user being able to understand the feedback given by PSD. The designers of persuasive design should consider whether their design is easy to understand. *Truth* can be regarded as the most important validity claim of speech-acts from a philosophical perspective. In many cases, PSD communicates with the user through various feedback mechanisms. The truth requirement demands that the feedback mechanism gives true information. *Truthfulness* is the property in human communication, to tell the truth in each context, also called ‘honesty’ or ‘truthfulness’ of the speaker. In PSD, it is not always clear who is the ‘author’ of the persuasion. It could be the PSD itself, the designer of the PSD, or the company or institution that implemented it. It might be enough to interpret ‘truthfulness’ in the case of PSD as the reliability and accuracy of a given feedback mechanism. Finally, *appropriateness* concerns the context of the given speech act. For example, a judge can say the word ‘guilty’ and establish a new social fact. But this is true

only if spoken under very specific circumstances by a judge in a courtroom, who is entitled to do so. The elements from the speech-act theory can function as guidelines for understanding and designing ethically acceptable PSD. It is something that designers can apply, and the guidelines can also support the teaching and learning process.

It raises the question: Can these guidelines shed light on the difference between a digital nudge and a dark pattern? The user's experience of the PSD in the digital environment and the context determines whether a PSD is perceived as a digital nudge or a dark pattern. Given that the users understand the elements of the design (comprehensibility), the real question is how they perceive the content (truth), the motives of the designer (truthfulness), and the context (appropriateness). Let us look at how a single PSD, such as loss aversion, can be incorporated into both digital nudges and dark patterns. Loss aversion is commonly applied in digital environments and relies on the automatic cognitive response of acting because failing to do so might lead to a lost opportunity. Loss aversion can be applied in the context of an online health program where feedback containing a nudge informs the user that time is running out to perform a certain task on time within a health program. If the user understands the message and the content of the message is true, let us focus on the motives of the designer and the context. The designer (or author) of the loss aversion message could be perceived as the health program itself, the designers of the health program, the institution that implements it (the user's healthcare provider or workplace), or simply the user herself if she freely installed it. Irrelevant to that, the motive of the designer is for the user to follow the health program. The context of being reminded to follow a health program is appropriate and, assuming it benefits the user, makes this an example of an ethical nudge. If we look at another example of loss aversion in the context of online shopping, where the interface would highlight that only a few items were left in stock. The message could be easily understood, but the user might question if it was true. In this example, the perceived designers could be the shopping site itself or the owners of the shopping site. The motive of this online shopping design could be to take advantage of the cognitive biases of the users to shift them towards making a purchase, fearing that if they do not act, the opportunity is lost. The motive of the user might be to only buy what they need and nothing more. If the context of this design has made the user buy something she did not need or want, then this design can be seen as an attempt at 'manipulation' rather than 'persuasion'. This example could therefore be categorized as a dark pattern. As illustrated in these examples of loss aversion, the contrast in the design of digital nudges vs. dark patterns lies in how the behavior change that they are intended to bring about aligns with the will of the users. This review of ethical considerations in PSD brings us to the discussion of how to successfully teach and learn about PSD.

2.3 Teaching and Learning about PSD

Technostress, technology addiction, and cyberbullying have been illustrated as the dark sides of social media use, specifically for vulnerable user groups such as teenage girls (Tarafdar et al., 2020; Califf et al., 2020; Lee et al., 2014; Chan et al., 2021). The way some social media and other digital means are designed can have a lasting impact, and while some digital infrastructures, such as social media, continue to be structurally faulty, there is a higher need to educate the users (Wang et al., 2023). One element of the structural issues can be attributed to the excessive use of PSD. As a call for action to reduce the impact of the use of dark design practices, ethical design, and educating designers and users on ethics in design has become an emerging area of interest. The definition of what ethics entail is, however, as one might suspect, widely debated (Mingers &

Walsham, 2010; Mulvenna, Boger, et al., 2017; Mulvenna, Hutton, et al., 2017). Our view on ethics in general draws from an understanding of moral principles that govern decision-making processes and choice architecture for a user. Mulvenna, Boger et al. (2017) define the concept of being ethical by design as a design philosophy that can be used for designers, while Islind and Willermark (2022) call for a pathway of educating both designers and users on PSD that is ethical by design and on how to utilize those. Although we see the value of applying an overarching design philosophy, we in this paper instead draw on ethical design as a practical concept, which is derived from the abovementioned design philosophy but entails two practical aspects of an ethical design process: i) an ethical way of illuminating the meaning behind PSD for the users by outlining ways of educating them, and; ii) the cultivation of ethical design as output, as a specific gain for the users by carving out pathways to point PSD out. In addition to that, teaching and learning the way ethical design, in contrast to less ethical use of design elements, can be spotted to vulnerable users, is a hot topic (Gray et al., 2023). Even though there is not yet consensus in the literature regarding ways in which ethical by design can be cultivated, most researchers agree that ethics: i) entail morality, goodness, care, and virtue; ii) can be understood as a field of philosophy and iii) hold discipline-specific standards in particular that are an addition to morality in general (Fore & Hess, 2020). The position of this paper is that all these aspects of ethics are relevant for design and use, and that there may be pivotal elements to how the introduction of PSD takes place. However, ethics can only partly be learned by increased knowledge of philosophy and standards. To address these issues of transfer, it becomes important to contextualize ethical dilemmas concerning aspects of morality, goodness, and virtue in practice through lived experience. Thus, teaching ethics through rules and codes of conduct outlines a static way, as rules are set in a reactive manner instead of in a proactive manner (Fore & Hess, 2020). Rules are in place to follow, but still, we face the issue of PSD everywhere we look online. Engaging in ethical design and use, understanding ethical dilemmas, and developing an ethical compass guided by morality, responsibility, goodness, and virtue from an early age entails a process of de-emphasizing objectivity and increased subjectivity through ‘lived activity’ (Riley & Lambrinidou, 2015; Islind & Willermark, 2022).

Based on the vast literature illustrated above, it is safe to say that educating vulnerable users and understanding the depth of the impact of specific elements used in our everyday internet life, specifically on teenage girls, can have a lasting impact. With that backdrop, we craft our case study with teenage girls, to examine their views on PSD in general and on digital nudging and dark patterns in particular to outline ways in which users can be informed and, in turn, how those can be designed, to be prepared when browsing the internet.

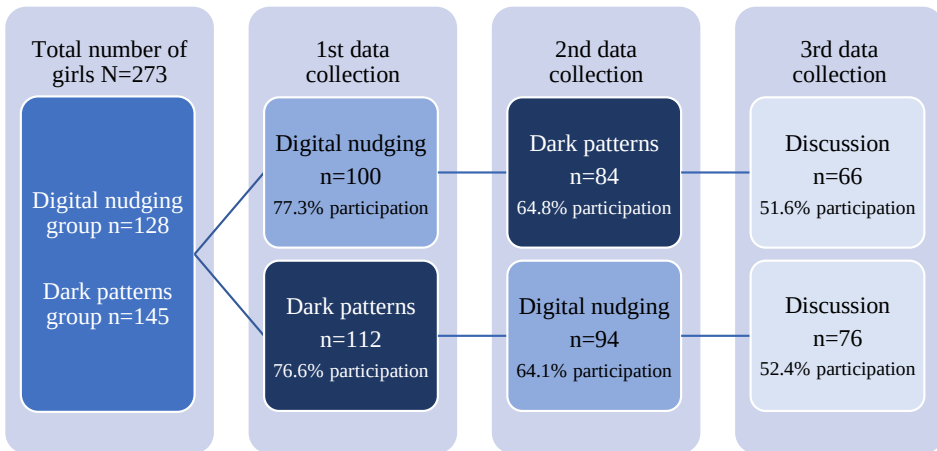
3. Methodology

The research approach for this paper is based on a case study. The approach in this case study is interpretive, where we study teenage girls' recognition of PSD, such as digital nudges and dark patterns. The data collected for our case study was of both a qualitative and quantitative nature. We collected the data through questionnaires (conducted in 2022, further elaborated on in 3.1) and open-ended questions. The empirical setting consists of fourteen-year-old girls in 9th grade attending an event hosted by a university in Scandinavia to encourage enrollment in informatics [country name removed for anonymity purposes]. The invitation to partake in this case study was extended to girls in 9th grade, and no other data collection was completed to identify gender nonconforming, queer, or nonbinary participants. Hence, everyone who identified as non-male was allowed to partake, not only those who were born as girls.

3.1 Case Study Design and Methods

For this paper, we conducted a one-step empirical data collection where 273 girls who participated in our data collection were randomly divided into groups. At the beginning of the workshop, the girls were informed that we would be collecting anonymous data for further analysis and research, and informed consent was granted before each data collection. The girls received two short presentations on PSD, followed by a guided discussion. They were asked to complete a questionnaire after each section. The subjects of the presentations were digital nudges, dark patterns, and a discussion on the design elements. We altered the order of the presentations on digital nudges and dark patterns to evaluate if the order had an impact on the results. We split the girls into two groups, where 47% of the girls ($n=128$) started with a presentation and questionnaire on digital nudging, hereinafter referred to as the *digital nudging group*. The girls then received a presentation and questionnaire on dark patterns. Followed by a discussion and a questionnaire with qualitative open-ended questions in written format. The other 53% ($n=145$) of the girls started with a presentation and questionnaire on dark patterns, hereinafter referred to as the *dark pattern group*, followed by a presentation and questionnaire on digital nudges. They also completed their participation with a final questionnaire reflecting on the design patterns in open-ended questions in written format. Figure 1 shows how we split the girls into groups, how we ordered the presentations and questionnaires, alongside the participation rates in each data collection step. The participation rate diminished with every data collection step presented during the session.

Figure 1. Data collection and answer rate



3.1.1 Presentations and Questionnaires

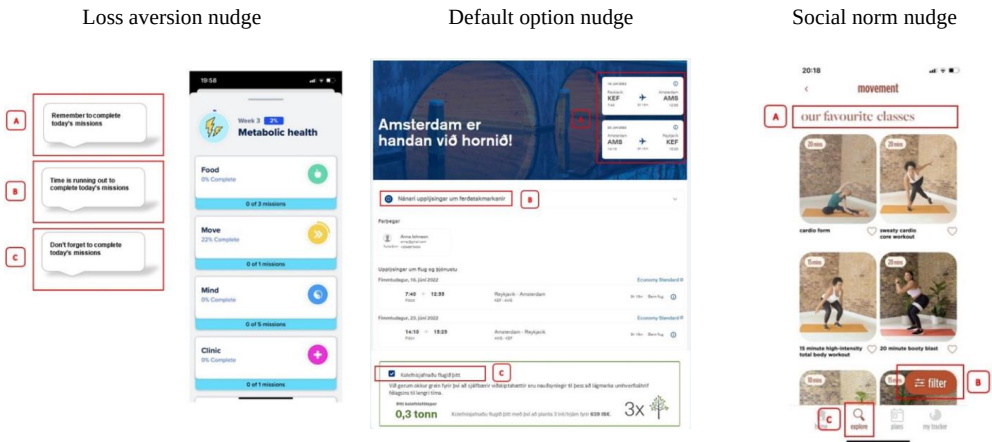
We used an active teaching method for the short lectures on digital nudges and dark patterns, where the lecturer plays the main role in communicating with students and explaining, encouraging them to discuss, and engaging them in the topic (Good & Lavigne, 2017). This method makes high demands on the lecturer in terms of knowledge of the subject and the ability to communicate, arouse interest, explain, and provoke thought. The role of the students is primarily to observe attentively and try to remember and understand, or reflect on the material (Wilén et al., 2000; Smaldino et al., 2008). We used a four-step interactive lecture structure for the presentations of PSDs.

1. *Connect* – At the beginning, we used an opener or a hook to draw the girl’s attention to the material. In our case, it was the title of the presentation “Decision making on the Internet – Are we sometimes being tricked?”
2. *Organize* – Very briefly, we explained to the girls that our session would be split into three parts and that they would need their smartphones in case they were willing to participate. Then we moved on to the definition of either digital nudges or dark patterns, depending on which group we were addressing.
3. *Reinforcement* – We used a variety of methods to make the material more memorable, including pictures, examples, and guided imagery. In the presentation on digital nudges, we talked about examples of healthy eating, learning a new language, healthy choices while grocery shopping, considering environmental sustainability, and opting for organ donation. In the lecture on dark patterns, we shared examples where people were tricked into subscriptions, continuous computer game playing, and buying unhealthy food.
4. *Exercise* – We paused the lecture to pose different questions to get the girls to reflect and think about the design methods. For example, in the section on digital nudges, we asked, “Do you sometimes feel like it would be good to get a little help making decisions?” In the end, the girls were asked to take out their smartphones to scan a QR code that would lead them to a questionnaire with screenshots of examples of either digital nudges or dark patterns. We walked through each screenshot with the girls, in case they were unfamiliar with the digital activity presented. Three areas in every screenshot were circled as options A, B, or C, and the girls were asked to mark the example of a digital nudge. They also had the option to answer that there was no digital nudge presented in the screenshot or that they did not recognize any digital nudging feature. The girls received a similar questionnaire after the lecture on dark patterns.

Three examples used for Digital Nudging:

The first screenshot was an example from a digital therapeutic application. We asked the girls if they recognized a message that was an example of a digital nudge. See Figure 2 below. (The right answer is a loss aversion notification informing the user that time is running out to follow the health program accordingly – option B). The second screenshot was an example of a flight booking engine with an overview of flight details, access to travel constraints, and default settings for carbon offsetting. See Figure 2 below. (The right answer is the default option being set for carbon offsetting – option C). The third screenshot was an example of a workout application with the app’s favorite classes, filters, and search options. See Figure 2 below. (The right answer is an example of appealing to social norms by selecting “our favorite classes” – option A)

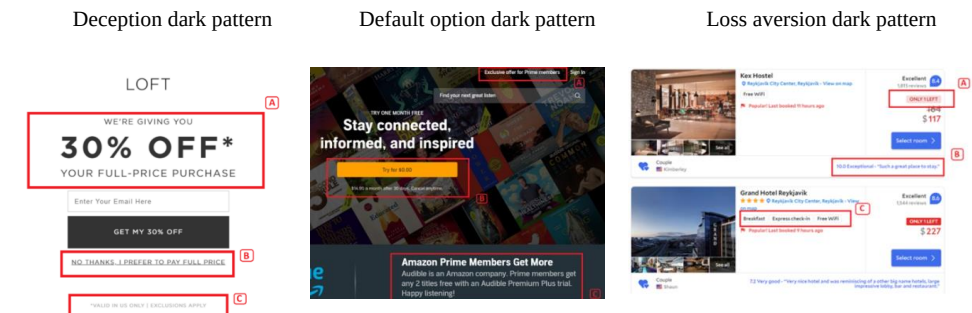
Figure 2. Examples of digital nudges



Three examples used for Dark Patterns:

The first screenshot was an example of a shopping site displaying an offer along with shopping terms. See Figure 3 below. (The right answer is an example of deception with terms written in very small letters – option C). The second screenshot was an example of a subscription site for a streaming service displaying applicable conditions, free offers with terms in very small letters, and detailed information. See Figure 3 below. (The right answer was the default subscription for a streaming service that was in small letters – option B). The third screenshot was an example of a hotel booking site displaying the number of rooms left, reviews, and service included. See Figure 3 below. (The right answer was the loss aversion example in the context of booking a hotel room – option A).

Figure 3. First example of a dark pattern



We also asked the girls about their attitudes towards every design example, which is covered in more detail in the appendix of this paper. We repeated this process from the definition through to step 4 with the other design method, depending on whether we started the session with a presentation on digital nudges or dark patterns.

3.1.2 Guided discussion

We closed every session with a guided discussion. The main goal of discussion and questioning methods is to engage students in discussion, debate, and the exchange of opinions. The lecturer's main task is to find challenging questions or other topics for students to discuss and to organize the discussions. This technique tests the lecturer's ability to create a situation where students feel they can express themselves freely. The role of the students is to take an active part in what is happening, show interest, discuss, and draw conclusions (Wilen, 2004). We guided the discussion towards trust and the internet and displayed guided imagery. At the end of the discussion, we summarized the material and encouraged the girls to also share their thoughts in writing in the third and final data collection.

3.2 Data Analysis

First, descriptive statistics were used to analyze the fixed response types. We used a two-proportion Z test to compare the share of correct scores between the groups. Second, the open-ended written answers were analyzed through qualitative thematic analysis. Details on the analysis of attitudes can be found in the appendix of this paper.

4. Results

In this section, we present the results of how well the girls recognize PSD after receiving presentations on persuasive design methods. We will also summarize the results from the guided discussion. In this paper, we focus on digital nudging, teaching, and learning. We published another paper that takes a deeper dive into the design, law, and dark patterns aspect of the dataset (Visescu et al., 2024).

4.1 Teenage girls' ability to recognize digital nudging and dark patterns

Overall, the girls had a hard time recognizing PSD. We measured how well the girls recognized the PSDs on the screenshots. On average, the girls were better at recognizing examples of dark patterns. They marked the correct answer for dark patterns at a slightly higher rate, 48.8%, compared to digital nudges, which were, on average, 41.0%. However, the difference is not significant. When we compared the groups, we saw that the girls in the dark pattern group, who were first exposed to dark patterns, did significantly better at recognizing PSD in three out of six screenshots. See a detailed analysis of how well the girls scored in Table 1 below.

Table 1. Recognition of PSD (% share of identifying the correct answer)

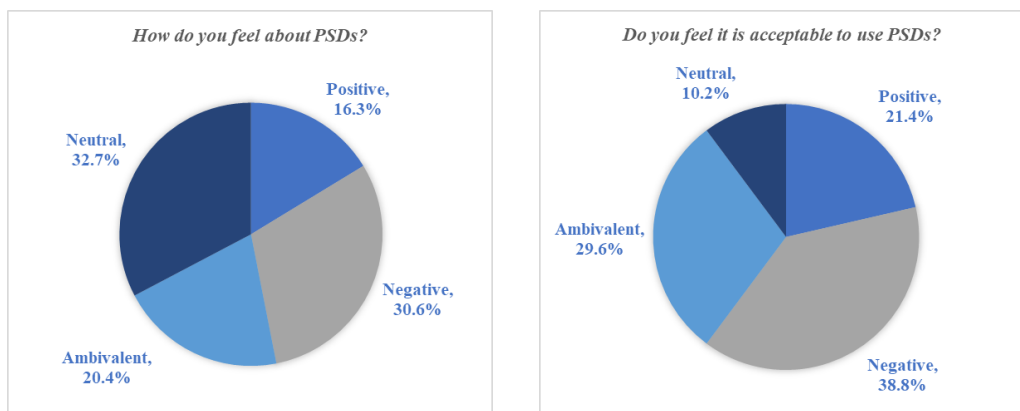
Questionnaire	PSD method	All (%)	Digital nudging group (%)	Dark patterns group %	z-score
Digital nudging	Loss aversion	32.0	34.0	29.8	0.629
	Default	45.9	37.0	55.3	-2.559*
	Social norms	45.4	48.0	42.6	0.762
Dark patterns	Deception	39.8	26.2	50.0	-3.370*
	Default	49.5	58.3	42.9	2.145*
	Loss aversion	57.1	48.8	63.4	-2.042*

Note: The percentage shows the share of correct answers.

4.2 Synthesis of the guided discussion

During our session with the girls, we spent an equal amount of time exploring digital nudges and dark patterns. However, dark patterns seemed to have a stronger impact on the girls. As mentioned above, the girls who were first exposed to dark patterns performed better in recognizing PSD and they had a stronger negative attitude towards dark patterns compared to the girls who were first exposed to digital nudges (see detailed discussion on attitudes in the appendix). This was also evident in the guided discussion, where the girls were asked to share an example of either digital nudging or dark patterns. Most of the girls shared an example of a dark pattern (68%), such as hidden costs or hidden subscriptions when shopping for clothes or make-up online. They also mentioned dark patterns in computer games and some social media apps. Only 32% mentioned nudges, such as those when grocery shopping or from language apps. We also saw this in the girls' answers to the question about their feelings towards PSD. Even though we talked about how PSD can be applied for the benefit of the users, only 16% of the girls had an overall positive attitude towards these design methods, mentioning they were *“Interesting”*, *“Smart”*, *“It is smart for companies”*, and *“Nudges can be positive”*. However, 31% of the girls had an overall negative attitude towards the design patterns, mentioning *“I feel it is unfair that we are being played with”*, *“It is annoying”*, and *“They make me feel uncomfortable”*. These answers suggest that some of the girls understand the motives of the designer (i.e., companies) and have negative feelings when the PSDs are not applied in the appropriate context. See Figure 4 (left) below for the summary of the girls' feelings toward PSDs.

Figure 4. Distribution of responses regarding questions about PSDs



Moreover, we asked the girls if it was acceptable to use these design methods. See Figure 4 (right) above. A common answer was that digital nudges were acceptable while dark patterns were not, indicating that the girls understood the message from the lectures: *“Nudges are good, dark patterns are bad”*. We also saw the tendency towards nudges in the answers we categorized as positive towards these design methods (21%): *“Yes for nudges”*, *“Yes, at moderation”*, *“Yes, if the intention is good”*, and *“Nudges should be used more often”*. 39% of the girls who had a negative response to the application of PSD simply wrote: *“No, not dark patterns”*. Then there were some

unique answers such as: *“Good for companies, bad for people”*, *“It is okay, but depends if there is real manipulation going on”*, and *“Nudges are cool, and I understand why companies would use dark patterns, but I would rather support a company that tries to make the world a better place”* illustrating a higher level of understanding of PSD. Again, we can see from the open-ended questions that even though the girls had a hard time recognizing PSD in the exercises after the presentations, some girls could clearly articulate that there are underlying motives behind these design patterns and that they can be applied in contexts that are appropriate or not. This can be related to the elements from the speech-act theory (Spahn, 2011) that can function as guidelines for understanding and designing ethically acceptable PSD. In the following section, we will develop practical guidelines for educators and designers for ethical PSD.

5. Discussion

Human cognition consists of two interconnected systems: one is unreflective, automatic, and based on emotional responses; the other is reflective, slow, and rational (Kahneman, 2003; Thaler and Sunstein, 2008; Meske and Amojo, 2020). Digital nudges are designed to influence that quick, instinctive side of our brains, what we might call our mental autopilot. Dark patterns do the same, but often with more questionable intent. This paper focuses on how these subtle design strategies, whether helpful or manipulative, tap into our cognitive shortcuts, a concept known as bounded relationality, and how they’re understood and used within the field of persuasive system design (PSD) in information systems.

Our case study contributes to the discourse surrounding ethics and responsibility within design and use, which delineates an emerging interest in research. Although the interest in the topic of ethics and responsibility is rising, the precise definition of ethics and responsibility through design and use remains a subject of extensive debate, as highlighted in various scholarly works (Mingers and Walsham, 2010; Mulvenna, Boger, et al., 2017; Mulvenna, Hutton, et al., 2017). Our conception of ethics and responsibility in this paper stems from a comprehension of moral principles governing an individual's decision-making processes, or lack thereof, by contributing with an enhanced understanding of how digital nudging and dark patterns are understood, and how they should be utilized through design.

While some scholars, such as Mulvenna, Boger et al. (2017), conceptualize ethical design as a comprehensive design philosophy, our approach in this paper deviates slightly. Here, we focus on ethical design as a practical concept, rooted in the overarching design philosophy but emphasizing two practical dimensions: first, an ethical compass guiding the designer, and second, the generation of ethical services as a tangible output that can serve the users. However, to understand the essence of ethics and responsibility when it comes to bounded relationality and the effects of digital nudging and dark patterns on our way of thinking and acting, we need to examine the roots of the users’ views on the topic, especially those in a vulnerable situation, hence our focus on teenage girls (Stahl, 2012).

We examined teenage girls' sense of recognition when faced with examples of PSDs. The findings explore teenage girls' comprehension of PSD, specifically digital nudges and dark patterns, and offer multifaceted insights into their understanding and ethical perceptions of these design elements. The approach adopted, captured through an interpretive case study, delved into the nuanced understanding of 273 fourteen-year-old girls. Notably, the order of presentation impacted

the results, hinting at the influence of sequence on perception. In light of our results and focusing on the design aspects of digital nudges and dark patterns, we have developed some practical suggestions on the “do’s and don’ts” of designing with PSDs including deception, default options, loss aversion, and social reference.

In the case study, we presented the girls with ethical dilemmas concerning aspects of morality, goodness, and virtue in screenshots that they could have come across in real life when browsing the Internet. Deception is one of the designed methods that we tested on the girls as a dark pattern where the user interface was difficult to understand with very small letters. This method breaks the most basic precondition of communication, that is *comprehensibility*, referring to the first element of the guidelines based on the speech-act (Spahn, 2011). Designers of persuasive design should consider whether their design is easy to understand. Furthermore, this approach goes against the “golden rule” principle that states that “creators of a persuasive technology should never seek to persuade a person or persons of something they themselves would not consent to be persuaded to do” (Berdichevsky & Neuenschwander, 1999). We were surprised to realize that the girls only demonstrated a moderate ability to recognize examples of PSDs. The line between positive and negative implications of digital technologies is not always clear, even for users with strong digital literacy. That has been illustrated in the literature, for example, where personal data can help individuals live healthier and longer lives, but can also challenge individual rights, obligations, and sense of dignity (Leidner and Tona, 2021; Tam et al., 2019). We suggest that designers should try to avoid using deception as a design method and focus on transparency. In particular, when targeting vulnerable groups such as children (Fogg, 2003). Adding transparency information to the interface, either explaining the digital nudge or its intended purpose or both, does not decrease its effectiveness (Bruns et al., 2018; Michels et al., 2024). We suggest that educators raise awareness of unethical design patterns, such as deception, among teenagers during classes in media literacy or digital education.

We presented the girls with examples of both digital nudges and dark patterns using the design methods of default options and loss aversion. Even though the contexts of the screenshots were not completely compatible (flight booking and streaming subscriptions for default options) and (health application and hotel booking for loss aversion examples) it was interesting to see that the girls recognized the dark patterns slightly better over digital nudges. Furthermore, the group that was initially exposed to dark patterns exhibited better recognition in several scenarios. Default options and loss aversion methods have the potential to significantly improve decision-making (Jachimowicz et al., 2019; Smith et al., 2019). Our suggestion for designers regarding loss aversion is perhaps to set some boundaries regarding the *truth* of the messages they are presenting (Spahn, 2011). Are they, for example, truly displaying the number of rooms left? When designing with responsibility, it is important to define ethical principles as the right and responsible action (Atkinson, 2006). Concerning default options, we suggest that the designer tries to make the design easily understood, perhaps signaling that the user is making a default choice of some sort, while respecting the autonomy of the user rather than only focusing on usability (Davis, 2009). When teaching about the design methods of default options and loss aversion, we suggest that educators focus on empowering teenagers and discuss human values such as “privacy” and “autonomy” so that they can navigate the Internet more independently. Designing ethical nudges is not only about making designs that are easily understood and present accurate information. Designers and educators should also reflect on the design and consider whether it is clear to the user who is the

“speaker” in the digital design. This is what the speech-act theory refers to as *truthfulness* (Spahn, 2011). For example, sharing with employees that default options to improve security have been applied to a computer system at a workplace could perhaps increase trust, user experience, and be considered as ethical or legitimate nudging (Janson and Barev, 2024). Furthermore, it could be straightforward to suggest default options with the motive of increasing safety at the workplace. However, using loss aversion to perhaps nudge employees to complete tasks on time could also be considered manipulation in some circumstances, if employees are already overworked. This brings us to the final guideline of the speech-act theory *appropriateness* (Spahn, 2011), which is something that both designers and educators need to consider regarding default options and loss aversion methods. To some extent, we need to trust the moral compass of the designers and let them bear the responsibility, but we also need to educate and raise strong teenagers who must rely on critical thinking. That is perhaps more sustainable in the long run. Moreover, our findings reveal that the way knowledge about dark patterns and digital nudging is cultivated through a practical understanding through exposure and education on responsible design, on the one hand, and responsible use, on the other hand, is imperative.

Finally, we presented the girls with an example of a digital nudge relying on social references. Considering social references, it is not only important to focus on transparency and responsibility, but it is also very relevant to explore the participation of users in the design process. A useful method for that would be the Participatory Design, which allows the users to be part of the design process and “is very much concerned with social learning and multi-stakeholder negotiation” (Davis, 2009). Social media plays a big role in the everyday life of teenagers, and the digital landscape is everchanging (Tarafdar et al., 2020; Califf et al., 2020; Lee et al., 2014; Chan et al., 2021), making it even more important to include vulnerable groups in the design process. Regarding attitudes, the girls displayed a more positive disposition towards digital nudges compared to dark patterns. The sequence of exposure significantly influenced their attitudes, with the girls in the digital nudging group introduced to digital nudges first, showcasing a more favorable view of subsequent dark pattern examples. Furthermore, our analysis of the qualitative findings also revealed interesting insights. While some perceived PSDs as intriguing and interesting, others felt manipulated and uncomfortable, especially when it came to the dark patterns. This range in emotions is expected as social norms and emotional regulation skills are still in active formation at the age of fourteen (Baccarella et al., 2018; Bristol and Mangleburg, 2005). The ethical dimension emerged prominently, with distinctions drawn between acceptable digital nudges and objectionable dark patterns. Ambivalence existed as well in some of our findings, underscoring a nuanced view that acknowledged contextual appropriateness and intent as key elements in the PSD elements. Digital artifacts are not created in a vacuum; designers play a crucial role and should consider that teenage girls are vulnerable users who are sensitive to social references. Our suggestion to educators is to encourage participation in digital design discussions. The level of social in-/exclusion of an information system, in particular concerning gender, is often not the result of good or poor choices or the lack of will but is simply the result of unawareness of inclusive social aspects (Olbrich et al., 2015). Furthermore, designers and system developers should be aware that (i) not all women everywhere constitute a homogenous group that possesses the same thoughts, feelings, and expectations about technology use, and (ii) the assumption that something such as a “women-friendly” design could exist (Olbrich et al., 2015). One does not need to have a technical background to have an opinion on how things should be presented in a digital environment. It is essential to emphasize that everyone’s voice should be heard, particularly those

from marginalized groups, such as children, teenagers, and girls. Designers and developers who use PSD should be aware of the existing asymmetrical power dynamics that enable them to influence users' attitudes, behaviour, and decision-making (Benner et al., 2022). They must balance transparency between users' needs and the PSD effects and effectiveness (Benner et al., 2022). Therefore, responsible and ethical PSD requires constant awareness of these asymmetrical power dynamics. The human-computer interaction literature provides guidelines, principles, and theory that aid designers and system developers in meeting the needs of diverse users (Schneiderman and Plaisant, 2010), as well as publicly available standards, such as those available from the World Wide Web Consortium (W3C, 2025).

These findings illustrate the importance of context and presentation order in shaping perceptions of PSDs among teenage girls, which in turn underscores the importance of ethical and responsible use of PSD for designers of information systems and those teaching about information systems. Additionally, the ethical considerations and diverse attitudes expressed highlight the need for responsible implementation of these design strategies for designers and outline the importance of cultivating an understanding amongst users. With responsibility, we can factor in both harmful and positive outcomes from the engagement with PSDs (Voegtlin et al., 2022).

5.1 Design Guidelines for Ethical Persuasive System Design

Based on our cumulative findings derived through our engagement with the empirical material, alongside our engagement with the literature through the discussion section of this paper, the contribution can be summarized in a set of design guidelines for ethical persuasive system design, which can be used by designers and educators. The design guidelines are three in total: (i) transparency, (ii) responsibility, and (iii) inclusion. We will present each of those in more detail below.

Transparency should be the main priority for designers and educators when designing or teaching user interfaces. For designers, this means making the design easily understood for teenage girls, always based on true content, while keeping in mind the needs and vulnerabilities of teenage girls. For educators, this means sharing the knowledge and awareness of the truthfulness and appropriateness of PSD.

Responsibility should be considered a defining feature of PSD when designing for vulnerable groups such as teenagers or children. Our case study shows that teenage girls were more accepting of dark patterns if they were first exposed to the benefits of digital nudges.

Inclusion refers to engaging users, including underrepresented groups like teenagers, directly in the design process. Gather their feedback and insights to ensure that design decisions meet user needs, while also preventing the creation of harmful usage patterns that could exploit vulnerabilities.

5.2 Limitations and Future Work

This paper has limitations that should be noted, and those can also serve as areas for future research. First, we did not follow each participant through all three data collections, as we did not see it as ethically justifiable to do so due to their young age and that type of design would have called for parental consent. It meant that we were limited in analyzing the drop-out throughout the

three data collection steps, and it would be interesting to analyze responses from the girls who participated in all three data collections. Second, we adopted five questions from the AttrakDiff scale for measuring attitudes that are traditionally used to measure user experience. Perhaps another method for measuring attitude would have been more appropriate for this type of case study. Third, in this case study we rely on teaching the girls about the design methods before asking them to identify different patterns and measuring their attitudes. Initially priming the participants about digital nudges and dark patterns may impact their experience. Fourth, in this case study we presented the teenage girls with screenshots of different PSDs. That limited us in following a strict digital nudge design method (Mirsch et. al., 2018), as we could not evaluate the actual outcome of the PSDs if the teenage girls had used the digital technology that was being explored. Fifth, we examined various contexts in the case study, such as online shopping, streaming, and hotel booking, which are distinctly different experiences. Some of the contexts might not be relevant for the demographic of teenage girls and therefore could impact their interest in participating in the case study. Sixth, educational practices vary internationally e.g. in Scandinavia there is a high focus on critical reflection as part of learning. This makes the general application of the results challenging whereas this can be significantly different in other countries. Finally, further research could explore these nuances across broader demographic spectra to inform more inclusive and ethically sound design practices while also exploring other vulnerable user groups to further the understanding of responsibility in the future of design and use.

6. Conclusions

Our paper shows that PSD is a powerful tool that needs to be handled with responsibility and care, in the appropriate context. We show with the findings drawn from our case study with the 273 teenage girls, that it is pivotal to cultivate an understanding amongst designers and users on the depth of the impact of PSD used in our everyday internet life, as the use of PSD can have a significant impact and need to be handled with care. We designed a case study where we examined teenage girls' recognition of PSD, both in the context where it is considered as digital nudges as well as in contexts considered as dark patterns. Furthermore, we explored teenage girls' views on PSD in general and on digital nudging and dark patterns in particular. The sequence of exposure significantly influenced the teenage girls' attitudes, where the girls who were first introduced to digital nudges, showcased a more favorable view of subsequent dark pattern examples. This is important when designing teaching material or information systems for teenage girls. The results suggest that exposure to digital nudges before dark patterns can bias users toward a positive attitude toward a possibly harmful context of a design element. This needs to be considered when teaching teenage girls about PSDs, and designers also need to be aware of this bias in attitudes. Teenage girls should not only be informed and educated about the impact of PSDs in different contexts but they should also be made aware of the bias that is related to the order of perception and educated on the dark side of PSD. This paper offers two main contributions. Firstly, we offer in-depth insights into the way teenage girls recognize PSDs. Our results show that teenage girls demonstrated a moderate ability to recognize PSD in feature design. We show both quantitatively and qualitatively what attitude teenage girls have towards digital nudges and dark patterns. Teenage girls have a significantly more positive attitude towards digital nudging compared to dark patterns. Furthermore, while some perceived PSDs as intriguing and interesting, others felt manipulated and uncomfortable, especially when it came to dark patterns. Second, we offer three concrete design guidelines to future designers and educators: (i) **Transparency** should be the main priority for designers and educators when designing or teaching about user interfaces, (ii)

Responsibility should be considered a defining feature of PSD when designing for vulnerable groups such as children or teenagers, and (iii) **Inclusion** refers to engaging users, including underrepresented groups like teenagers, directly in the design process. Summed up, our findings offer valuable insights into how teenage girls perceive and navigate digital nudges and dark patterns, emphasizing the pivotal role of context, presentation sequence, responsibility, and ethical considerations in shaping their attitudes and comprehension of persuasive design strategies.

References

- Ahuja, S., Chan, Y. E., & Krishnamurthy, R. (2023). Responsible innovation with digital platforms: Cases in India and Canada. *Information Systems Journal*, 33(1), 76-129.
- Arno, A., & Thomas, S. (2016). The efficacy of nudge theory strategies in influencing adult dietary behaviour: a systematic review and meta-analysis. *BMC public health*, 16(1), 1-11.
- Atkinson, B. M. (2006, May). Captology: A critical review. In *International conference on persuasive technology* (pp. 171-182). Berlin, Heidelberg: Springer Berlin Heidelberg.
- AttrakDiff, 2023. <https://www.attrakdiff.de/index-en.html>
- Austin, J. L. (1962). *How to do things with words*. Oxford: Clarendon.
- Baccarella, C. V., Wagner, T. F., Kietzmann, J. H., & McCarthy, I. P. (2018). Social media? It's serious! Understanding the dark side of social media. *European Management Journal*, 36(4), 431-438.
- Berdichevsky, D., & Neuenschwander, E. (1999). Toward an ethics of persuasive technology. *Communications of the ACM*, 42(5), 51-58.
- Berger, M., Müller, C., & Nüske, N. (2020, December). Digital Nudging in Online Grocery Stores- Towards Ecologically Sustainable Nutrition. In *ICIS*.
- Bergram, K., Djokovic, M., Bezençon, V., & Holzer, A. (2022, April). The digital landscape of nudging: A systematic literature review of empirical research on digital nudges. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).
- Bristol, T., & Mangleburg, T. F. (2005). Not telling the whole story: Teen deception in purchasing. *Journal of the Academy of Marketing Science*, 33(1), 79-95.
- Bruns, H., Kantorowicz-Reznichenko, E., Klement, K., Jonsson, M. L., & Rahali, B. (2018). Can nudges be transparent and yet effective? *Journal of Economic Psychology*, 65, 41-59.
- Califf, C. B., Sarker, S., & Sarker, S. (2020). The bright and dark sides of technostress: A mixed-methods study involving healthcare IT. *MIS quarterly*, 44(2).
- Cebollero-Salinas, A., Orejudo, S., Cano-Escoriaza, J., & Íñiguez-Berrozpe, T. (2022). Cybergossip and Problematic Internet Use in cyberaggression and cybervictimisation among adolescents. *Computers in Human Behavior*, 131, 107230.
- Chan, T. K., Cheung, C. M., & Lee, Z. W. (2021). Cyberbullying on social networking sites: A literature review and future research directions. *Information & Management*, 58(2), 103411.
- Cho, I., & Bates, D. W. (2018). Behavioral economics interventions in clinical decision support systems. *Yearbook of medical informatics*, 27(1), 114.

Clausen, S., Marx, J., Mirbabaie, M., & Stieglitz, S. (2022). From Dark Patterns to Digital Sludging – Mapping the Ethical Debate on Controversial Persuasive System Design.

Davis, J. (2009, April). Design methods for ethical persuasive computing. In *Proceedings of the 4th International Conference on Persuasive Technology* (pp. 1-8).

Fogg, B. J. (2003). Persuasive technology: using computers to change what we think and do. *Ubiquity*, 2002(December), 2.

Fore, G. A., & Hess, J. L. (2020). Operationalizing ethical becoming as a theoretical framework for teaching engineering design ethics. *Science and engineering ethics*, 26(3), 1353-1375.

Good, T. L., & Lavigne, A. L. (2017). Looking in classrooms. Routledge.

Gram-Hansen, S. B. (2021, April). Defining Features of Behavior Design: Considering Context. In *International Conference on Persuasive Technology* (pp. 308-319). Cham: Springer International Publishing.

Gray, C. M., Kou, Y., Battles, B., Hoggatt, J., & Toombs, A. L. (2018, April). The dark (patterns) side of UX design. In *Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1-14).

Gray, C. M., Sanchez Chamorro, L., Obi, I., & Duane, J. N. (2023, July). Mapping the Landscape of Dark Patterns Scholarship: A Systematic Literature Review. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference* (pp. 188-193).

Habermas, J. (1993). Justification and application: Remarks on discourse ethics.

Hassenzahl, M. (2018). The thing and I: understanding the relationship between user and product. *Funology 2: from usability to enjoyment*, 301-313.

Hummel, D., & Maedche, A. (2019). How effective is nudging? A quantitative review on the effect sizes and limits of empirical nudging studies. *Journal of Behavioral and Experimental Economics*, 80, 47-58

Isleifsdottir, J., & Larusdottir, M. (2008, June). Measuring the user experience of a task oriented software. In *Proceedings of the international workshop on meaningful measures: valid useful user experience measurement* (Vol. 8, pp. 97-101). Toulouse, France: Institut de Recherche en Informatique de Toulouse.

Islind, A. S., & Willermark, S. M. J. (2022). Becoming a Designer: The value of sensitive design situations for teaching and learning ethical design and design theory. *Scandinavian Journal of Information Systems*, 34(1), 1.

Jachimowicz, J. M., Duncan, S., Weber, E. U., & Johnson, E. J. (2019). When and why defaults influence decisions: A meta-analysis of default effects. *Behavioural Public Policy*, 3(2), 159-186.

- Janson, A., & Barev, T. J. (2024). Making the default more legitimate—the role of autonomy and transparency for digital privacy nudges. *Information Technology & People*.
- Johnson, E. J., & Goldstein, D. (2003). Do defaults save lives? ed: American Association for the Advancement of Science.
- Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American economic review*, 93(5), 1449-1475.
- Kahneman, D., Lovallo, D., & Sibony, O. (2011). Before you make that big decision. *Harvard business review*, 89(6), 50-60.
- Kight, R., & Gram-Hansen, S. B. (2019). Do ethics matter in persuasive technology?. In *Persuasive Technology: Development of Persuasive and Behavior Change Support Systems: 14th International Conference, PERSUASIVE 2019, Limassol, Cyprus, April 9–11, 2019, Proceedings 14* (pp. 143-155). Springer International Publishing.
- Lee, Y. K., Chang, C. T., Lin, Y., & Cheng, Z. H. (2014). The dark side of smartphone usage: Psychological traits, compulsive behavior and technostress. *Computers in human behavior*, 31, 373-383.
- Leidner, D. E., & Tona, O. (2021). The CARE Theory of Dignity Amid Personal Data Digitalization. *MIS Quarterly*, 45(1).
- Lembcke, T. B., Engelbrecht, N., Brendel, A. B., Herrenkind, B., & Kolbe, L. M. (2019). Towards a Unified Understanding of Digital Nudging by Addressing its Analog Roots. In PACIS (p. 123).
- Lembcke, T. B., Engelbrecht, N., Brendel, A. B., & Kolbe, L. M. (2020). To Nudge or not to Nudge: Ethical Considerations of Digital nudging based on its Behavioral Economics roots. In *ECIS*.
- Lobschat, L., Mueller, B., Eggers, F., Brandimarte, L., Diefenbach, S., Kroschke, M., & Wirtz, J. (2021). Corporate digital responsibility. *Journal of Business Research*, 122, 875-888.
- Mathur, A., Acar, G., Friedman, M. J., Lucherini, E., Mayer, J., Chetty, M., & Narayanan, A. (2019). Dark patterns at scale: Findings from a crawl of 11K shopping websites. *Proceedings of the ACM on Human-Computer Interaction*, 3(CSCW), 1-32.
- Meske, C., & Amojo, I. (2020). Ethical guidelines for the construction of digital nudges. *arXiv preprint arXiv:2003.05249*.
- Meske, C., Amojo, I., & Müller, C. (2022). Online flight booking: digital nudging to decrease aviation-related carbon emissions. *Information Technology & People*.
- Mettler, T., & Stepanovic, S. (2023). Acceptable nudge strategies to incentivize the use of wearables and physiolytics at work: A Q-methodology examination. *Journal of Information Technology*, 02683962231173706.

- Michels, L., Ochmann, J., Schmitt, K., Laumer, S., & Tiefenbeck, V. (2024). Salience, transparency, and self-nudging: a digital nudge to promote healthier food product choices. *European Journal of Information Systems*, 33(5), 717-747.
- Mihale-Wilson, C., Hinz, O., van der Aalst, W., & Weinhardt, C. (2022). Corporate digital responsibility: relevance and opportunities for business and information systems engineering. *Bus Inf Syst Eng* 64 (2): 127–132.
- Mingers, J., & Walsham, G. (2010). Toward ethical information systems: The contribution of discourse ethics. *MIS quarterly*, 833-854.
- Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017), 634-648
- Mirsch, T., Lehrer, C., & Jung, R. (2018). Making digital nudging applicable: The digital nudge design method.
- Mulvenna, M., Boger, J., & Bond, R. (2017, September). Ethical by design: A manifesto. In *Proceedings of the European Conference on Cognitive Ergonomics* (pp. 51-54).
- Mulvenna, M., Hutton, A., Coates, V., Martin, S., Todd, S., Bond, R., & Moorhead, A. (2017). Views of caregivers on the ethics of assistive technology used for home surveillance of people living with dementia. *Neuroethics*, 10, 255-266.
- Müller, K. W., Dreier, M., Beutel, M. E., Duven, E., Giralt, S., & Wölfling, K. (2016). A hidden type of internet addiction? Intense and addictive use of social networking sites in adolescents. *Computers in Human Behavior*, 55, 172-177.
- Olbrich, S., Trauth, E. M., Niedermann, F., & Gregor, S. (2015). Inclusive design in IS: Why diversity matters. *Communications of the Association for Information Systems*, 37(1), 37.
- Reiner, I., Tibubos, A. N., Hardt, J., Müller, K., Wölfling, K., & Beutel, M. E. (2017). Peer attachment, specific patterns of internet use and problematic internet use in male and female adolescents. *European child & adolescent psychiatry*, 26, 1257-1268.
- Riley, D. M., & Lambrinidou, Y. (2015, June). Canons against cannons? Social justice and the engineering ethics imaginary. In *2015 ASEE Annual Conference & Exposition* (pp. 26-322).
- Rogers, K. (2019). US teens use screens more than seven hours a day on average—and that’s not including school work. *CNN*.
- Smaldino, S. E., Lowther, D. L., Russell, J. D., & Mims, C. (2008). Instructional technology and media for learning.
- Salovaara, A., Lyytinen, K., & Penttinen, E. (2019). High reliability in digital organizing: Mindlessness, the frame problem, and digital operations. *MIS quarterly*.

- Schneider, C., Weinmann, M., & Vom Brocke, J. (2018). Digital nudging: guiding online user choices through interface design. *Communications of the ACM*, 61(7), 67-73.
- Selnes, F. N. (2023). Fake news on social media: Understanding teens'(Dis) engagement with news. *Media, Culture & Society*, 01634437231198447.
- Searl, J. (1969). *Speech acts*. Cambridge: Cambridge University Press.
- Smahel, D., Machackova, H., Mascheroni, G., Dedkova, L., Staksrud, E., Ólafsson, K., ... & Hasebrink, U. (2020). EU Kids Online 2020: Survey results from 19 countries.
- Smids, J. (2012). The voluntariness of persuasive technology. In *Persuasive Technology. Design for Health and Safety: 7th International Conference, PERSUASIVE 2012, Linköping, Sweden, June 6-8, 2012. Proceedings 7* (pp. 123-132). Springer Berlin Heidelberg.
- Smith, B. O., Shrader, R., White, D. R., Wooten, J., Dogbey, J., Nath, S., ... & Rosenman, R. (2019). Improving student performance through loss aversion. *Scholarship of Teaching and Learning in Psychology*, 5(4), 278.
- Schmitz, L., Richert, E., Arnardottir, E. S., & Islind, A. S. (2024). Nudging with Dignity: A Critical Examination of when and how to use Digital Nudging. *Scandinavian Conference of Information Systems*.
- Shneiderman, B., & Plaisant, C. (2010). *Designing the user interface: strategies for effective human-computer interaction*. Pearson Education India.
- Stahl, B. C. (2012). Morality, ethics, and reflection: a categorization of normative IS research. *Journal of the association for information systems*, 13(8), 1.
- Spahn, A. (2012). And lead us (not) into persuasion...? Persuasive technology and the ethics of communication. *Science and engineering ethics*, 18, 633-650.
- Stoilova, M., Livingstone, S., & Khazbak, R. (2021). Investigating Risks and Opportunities for Children in a Digital World: A rapid review of the evidence on children's internet use and outcomes.
- Susser, D., Roessler, B., & Nissenbaum, H. (2019). Online manipulation: Hidden influences in a digital world. *Geo. L. Tech. Rev.*, 4, 1.
- Tam, K. Y., Feng, K. Y., & Kwan, S. (2019). The role of morality in digital piracy: Understanding the deterrent and motivational effects of moral reasoning in different piracy contexts. *Journal of the Association for Information Systems*, 20(5), 3.
- Tarafdar, M., Maier, C., Laumer, S., & Weitzel, T. (2020). Explaining the link between technostress and technology addiction for social networking sites: A study of distraction as a coping behavior. *Information Systems Journal*, 30(1), 96-124.
- Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. Yale University Press.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *science*, 185(4157), 1124-1131.

Visescu, I., Jóhannsdóttir, L., Islind A. S., (2024) Whistling in the Dark: Inability to Recognize Dark Patterns and Lack of Concern Amongst Teenagers. presentation at the ItAIS 2024 conference, which will be held in Piacenza on October 11th-12th, 2024.

Voegtlin, C., Scherer, A. G., Stahl, G. K., & Hawn, O. (2022). Grand societal challenges and responsible innovation. *Journal of Management Studies*, 59(1), 1-28.

W3C. (2025). Web design and applications. Retrieved from <http://www.w3.org/standards/webdesign/>

Wang, R., Bush-Evans, R., Arden-Close, E., Bolat, E., McAlaney, J., Hodge, S., ... & Phalp, K. (2023). Transparency in persuasive technology, immersive technology, and online marketing: Facilitating users' informed decision making and practical implications. *Computers in Human Behavior*, 139, 107545.

Weinmann, M., Schneider, C., & Brocke, J. V. (2016). Digital nudging. *Business & Information Systems Engineering*, 58, 433-436.

Wilén, W., Ishler, M., Hutchison, J., & Kindsvatter, R. (2000). *Dynamics of effective teaching*. Addison Wesley Longman, Inc., Allyn & Bacon, Order Processing Department, PO Box 10695, Des Moines, IA 10695.

Wilén, W. W. (2004). Refuting misconceptions about classroom discussion. *The Social Studies*, 95(1), 33-39.

Willemark, S., & Islind, A. S. (2022). CHOICE ARCHITECTURE, FRIEND, OR FOE? FUTURE DESIGNERS' PERSPECTIVE ON THE ETHICS OF DIGITAL NUDGES.

Zhang, Y., Bellamy, R. K., & Kellogg, W. A. (2015, April). Designing information for remediating cognitive biases in decision-making. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems* (pp. 2211-2220)

Appendix:

Method for Measuring Attitudes Towards PSD

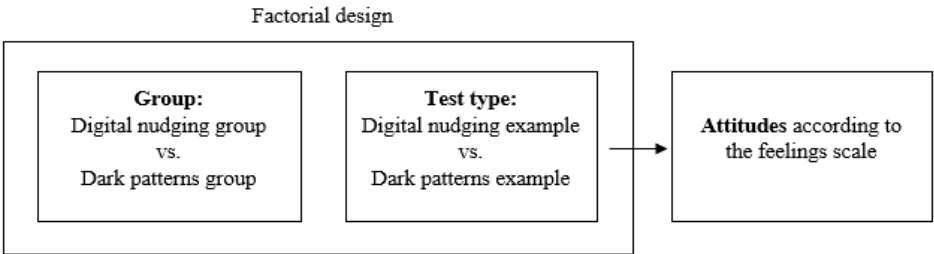
Following the presentations on digital nudges and dark patterns, we asked the girls to answer questionnaires with screenshot examples (see section 3.1.1. above for details). After every example, the girls were asked to rate how they felt about the screenshot by answering 5 questions drawn from the AttrakDiff scale (AttrakDiff, 2023). See Table 2 below with the scales. The AttrakDiff scale is designed to measure user experience, and we adapted and shortened the scale to measure the girls' attitudes. In this case study, we used four scales that measure attraction and the global appeal of the examples (Hassenzahl, 2018). In addition to that, we used one scale measuring the pragmatic quality of the examples (confusing to clearly structured), referring to what makes people able to fulfill their goals using the proposed digital elements and finding out how to use it on their own (Isleifsdottir and Larusdottir, 2008).

Table 2. The scales that the girls were asked to rate their attitude toward PSD examples

How did you find the example in the screenshot on a scale from 0 to 10?	
Bad	Good
Confusing	Clearly structured
Discouraging	Motivating
Unpleasant	Pleasant
Disagreeable	Likeable

To assess the attitudes, we designed a full factorial design with factors *group* and *test type*. Figure 5 below illustrates the different components of the methodology. We take the order of the group into account as the *digital nudging group* first received a presentation on digital nudging and the *dark patterns group* first received a presentation on dark patterns. We also consider if the girls are evaluating an example of digital nudging or dark patterns. For each example, the girls evaluated five scales, and the score used in the full factorial design for each example is the average score of the five scales.

Figure 5. Research methodology components



Note: Attitudes are scored on a scale inspired by the AttrakDiff scale

Data Analysis of Attitudes

We used a two-sample t-test assuming equal variance to compare the different attitude scores between the groups. In the factorial analysis, we analyze how the two factors and their interaction - *group* and *test type* - affect the scoring of attitudes by the teenage girls. Lastly, we applied analysis of variance (ANOVA) with interaction effects on the dataset.

Results on the Attitudes Towards Digital Nudges and Dark Patterns

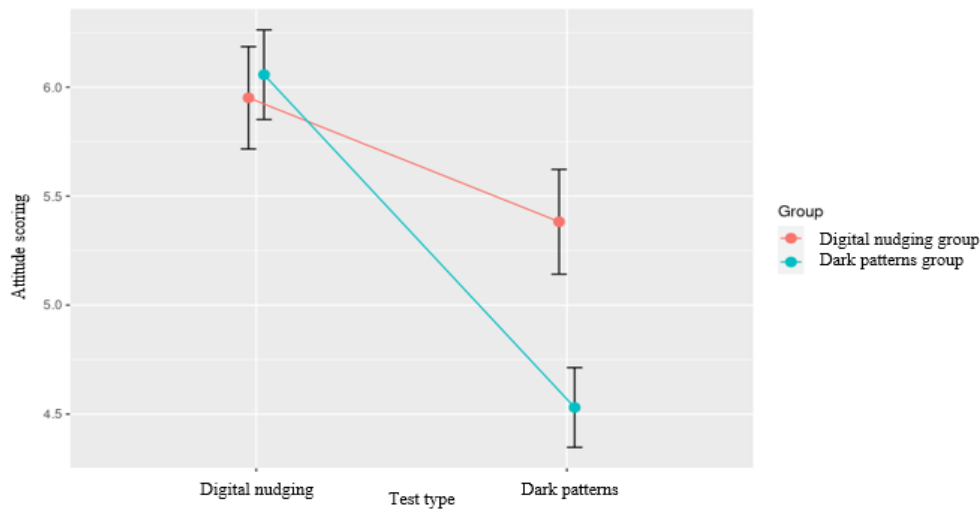
A factor analysis of the groups of girls and types of tests gives us information about the impact of each factor on the scoring of attitudes. For this analysis, 100 teenage girls in the digital nudging group and 112 teenage girls in the dark patterns group are included (Factor *group* where the digital nudging group started with digital nudging and the dark pattern group started with dark patterns). Out of this population, 582 digital nudging examples were scored, and 588 dark patterns examples were scored (Factor *Test type*). The results of the full factorial analysis can be observed in Table 3 below. We find that both the factor *group* and *test type*, as well as their interaction, are strongly significant, which means that the girls in the digital nudging group are more positive toward these types of PSD and that teenage girls are also more positive toward digital nudging compared to dark patterns.

Table 3. Factor analysis for attitude scoring

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Group	1	63	62.2	18.07	2.29e-05 ***
Test type	1	335	335.4	96.38	< 2.29e-05 ***
Group:Test type	1	66	66.4	19.09	1.36e-05 ***
Residuals	1166	4058	3.5		
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

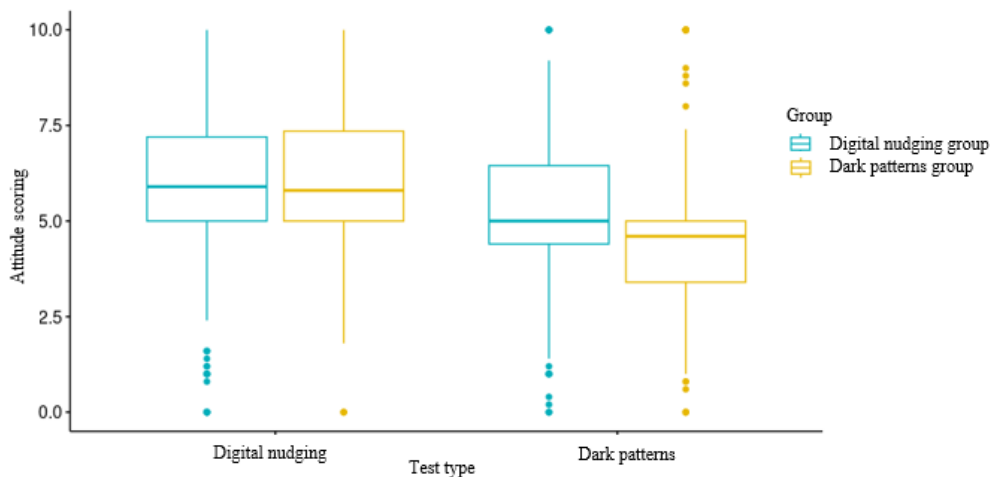
In Figure 6 we present a means plot that shows that the interaction effect between *group* and *test type* is significant. The plot shows that the mean attitude score on the nudging test is similar for both groups, with the mean score for the dark patterns group being slightly higher. The difference between the two groups is much greater when looking at the attitude score for dark patterns, where the digital nudging group scored significantly higher than the dark patterns group. It is evident from this plot, that the order of the presentation mattered for the girls' attitude.

Figure 6. Means plot of attitude scoring by groups and test type



As can be seen in Figure 7, the girls had a more positive attitude towards digital nudging compared to dark patterns. In addition, the teenage girls in the digital nudging group had a more positive attitude towards the dark patterns compared to the girls in the dark patterns group.

Figure 7. Boxplot of attitude scoring



Overall, the girls had a significantly more positive attitude towards the examples displaying digital nudges compared to examples of dark patterns. Of the five elements that measure the attitudes on a scale from 0-10, digital nudges scored 5.92 while dark patterns scored 4.90. When we compared the attitude of the girls in each group there was no significant difference towards digital nudges.

However, the digital nudging group, who first received a presentation on digital nudges, had a significantly more positive attitude towards dark patterns. See Table 4 below for the results of the significant tests on the difference in attitudes of the groups of girls by each example.

Table 4. Attitudes Towards Digital Nudges and Dark Patterns by each example

Questionnaire	PSD method	Digital nudging group mean	Dark patterns group mean	p-value
Nudging	Loss aversion	5.98	6.04	0.336
Nudging	Default option	5.78	5.73	0.364
Nudging	Social norms	5.90	6.09	0.09
Dark patterns	Deception	5.43	4.37	<0.001*
Dark patterns	Default	5.35	4.46	<0.001*
Dark patterns	Loss aversion	5.36	4.76	<0.001*
<i>Note: Calculated the mean score of the five attitude answers for each example</i>				

The results from the analysis of attitudes can be summarized in a practical guideline for educators. If the educator aims to raise awareness of the harmfulness of dark patterns, then it is better to structure the lecture by starting with a presentation on dark patterns instead of digital nudges. Then teenage girls are more likely to have a stronger negative attitude towards dark patterns.