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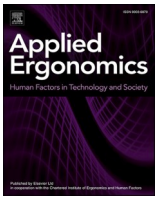

Designing digital patient experiences: The digital health design framework

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ABSTRACT

Background: Digital health (DH) brings considerable benefits, but it comes with potential risks. Human Factors (HF) play a critical role in providing high-quality and acceptable DH solutions. Consultation with designers is crucial for reflecting on and improving current DH design practices.
Objectives: We investigated the general DH design processes, challenges, and corresponding strategies that can improve the digital patient experience (PEx).
Methods: A semi-structured interview study with 24 design professionals. All audio recordings were transcribed, deidentified, grammatically corrected, and imported into ATLAS.ti for data analysis. Three coders participated in data coding following the thematic analysis approach.
Results: We identified eight DH design stages and grouped them into four phases: preparation, problem-thinking, problem-solving, and implementation. The analysis presented twelve design challenges associated with contextual, practical, managerial, and commercial aspects that can hinder the design process. We identified eight common strategies used by respondents to tackle these challenges.
Conclusions: We propose a Digital Health Design (DHD) framework to improve the digital PEx. It provides an overview of design deliverables, activities, stakeholders, challenges, and corresponding strategies for each design stage.

1. Introduction

According to the World Health Organization, "a health system consists of all organizations, people, and actions whose primary intent is to promote, restore or maintain health. This includes efforts to influence determinants of health as well as more direct health-improving activities" (World Health Organization, 2007). As they state in their Health System Challenges framework (World Health Organization, 2018) there are still many health needs and problems that need to be addressed. Digital health (DH) solutions, such as DH platforms (World Health Organization, 2020), patient portals (Irizarry et al., 2015), mobile health (mHealth) applications (Free et al., 2013), electronic health (eHealth) records (EHR), and appointment scheduling apps (Ammenwerth et al., 2012), have a great potential to tackle many of our current health system challenges, such as access to healthcare information and enhanced self-management (World Health Organization, 2018; Gopal et al., 2019). However, the benefits of DH have not yet been fully demonstrated due to, for example, poor interaction design and patient experience (PEx) (Wang et al., 2022a, 2022b, 2024). Human-Centered Design (HCD) has the potential to meet these underlying healthcare user needs (Persson, 2017; Martin et al., 2005; Erwin and Krishnan, 2016a, 2016b). HCD is defined in ISO 9241-210 as, "an approach to systems design and development that aims to make interactive systems more useable by focusing on the use of the system and applying Human Factors/Ergonomics (HFE) and usability knowledge and techniques" (Aasdahl et al., 2020). However, applying HCD requires a holistic process and poses many challenges (Melles et al., 2021; Carayon et al., 2020). Dedicated approaches to designing digital patient experiences are needed (Wang et al., 2022a, 2022b), taking into account the many stakeholders working at multiple interfaces in healthcare (Carayon et al., 2020). In this study, we provide a framework to improve the HCD process in both digital healthcare practice and the digital PEx.

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1.1. Design processes and frameworks in digital health

Dubberly stated (Dubberly, 2004), "Our processes determine the quality of our products". Although many well-known HFE and HCD frameworks and methods, from contextual mapping for understanding human needs to co-creation for generating design solutions, are common to healthcare (Melles et al., 2021), they need to be adapted to DH. Studies show that while design processes across different domains seem similar at an abstract level (Clarkson and Eckert, 2010), their emphasis on specific activities often varies significantly between domains (Eckert et al., 2004; Wang et al., 2022c). This is also true for DH, as we demonstrated in a previous publication (Wang et al., 2022c). For example, the Double Diamond framework (Council, 2019) is often used by many designers to manage their DH design processes, but their design values and requirements are different (Wang et al., 2022c). Obviously, to understand how to better design for healthcare, we can obtain insights from design challenges and opportunities in other mature domains. Bate and Robert (2006) introduced evidence-based design (EBD) in 2006 and stated that "good design" of healthcare services—and the resulting "good experience"—is essentially no different from good design in any sector, including performance (functionality), engineering (safety), and the aesthetics of experience (usability). In addition, Jones argues that given the complexity of the healthcare industry, traditional User-Centered Design (UCD) approaches are inadequate to address the specific problems in the healthcare domain (Jones, 2013). Groeneveld et al. agree and add that, considering the vulnerable target users and complex design contexts, healthcare designers are facing more challenges than some designers who work in non-healthcare design domains (Groeneveld et al., 2018). Regarding the functionality, safety, and usability of DH systems, more rigorous EBD and HCD considerations are needed (Tsekleves and Cooper, 2017).

A design process can be considered a rational process with defined phases that guide designers towards achieving specific goals at each phase. Current examples that focus on general design processes across different domains are the four phases (discover, define, develop, and deliver) in the British Design Council's evolved Double Diamond innovation framework (Council, 2019), the three main phases (inspiration, ideation, and implementation) in IDEO's Field Guide to HCD (IDEO.org, 2015), and the five modes (empathize, define, ideate, prototype, and test) in Stanford Design School's Design Thinking Process Guide (Hasso Plattner Institute of Design at Stanford, 2010). In addition, some others also provide design process directions specifically for healthcare (Healthcare Design Group CEDC, 2020) or the DH field (Mummah et al., 2016), such as the six elements (understand the context, define the problem, develop the solution, collect the evidence, make the case, and manage the plan) in the Improving Improvement Toolkit (Healthcare Design Group CEDC, 2020) to understand the healthcare system's complexity and promote improvement in healthcare, as well as the ten phases (empathize, specify, ground, ideate, prototype, gather, build, pilot, evaluate, and share) in the Integrate, Design, Assess, and Share (IDEAS) framework to integrate behavioral theory, design thinking, user-centered design, rigorous evaluation, and dissemination approaches to guide the development and evaluation of more effective digital interventions (Mummah et al., 2016). However, to our knowledge, there are no design frameworks for improving PEx in DH. The lack of transparency in current DH design practices is a result of the heterogeneous nature of the healthcare industry, combined with companies' reluctance to disclose their development processes (Martin et al., 2012). There are many poorly designed DH care systems (Persson et al., 2021), highlighting the need for a more sector-specific design process framework that guides DH design practices.

1.2. Design challenges and strategies in digital health

Designing for DH is challenging and requires thorough preparation. Healthcare itself is significantly conflicted, complex, and adaptive (Perry et al., 2021), and is highly regulated and constrained by many factors, such as data security and privacy, which limit the efficient use of health information (Gopal et al., 2019). DH is often utilized by multiple user groups such as patients and healthcare providers in various healthcare settings, from preventing, diagnosing to treating diseases (Martin et al., 2012; Perry et al., 2021). This dynamic environment demands a collaborative approach that caters to multiple stakeholders (Erwin and Krishnan, 2016b) and encourages interdisciplinary team engagements (Dinh et al., 2020). However, the goals and values among involved parties may not necessarily be aligned, and the roles and responsibilities of the stakeholders are often unclear upfront (Kleinsmann et al., 2015; Shadlyn et al., 2022). Conflicting goals across stakeholders, such as profitability, convenience, and patient-centeredness, lead to divergent approaches and stagnate performance improvement (Porter, 2010).

Designers often play a critical role in recognizing, prioritizing, and acting on stakeholders' needs, while also facilitating interdisciplinary collaborations between disciplines (Kleinsmann et al., 2015; Dong et al., 2015; Kessler et al., 2021). Despite extensive research on the needs of patients and healthcare providers, less is known about the design processes, challenges, and strategies that designers encounter in practice (Wang et al., 2022b). To improve existing healthcare design practices, it is therefore paramount to involve design practitioners (Martin et al., 2005). Therefore, in the current study, we focused on investigating designers' perceptions, understandings, and experiences in terms of DH design and digital PEx improvements.

1.3. Research Objectives

The overarching goal of this study was to obtain insights into current Human-Centered Design (HCD) practices in the digital health (DH) area in order to propose a generic DH design process. In this two-stage process, we first identified common HCD processes in DH, including design phases, stages, activities, stakeholders, and deliverables throughout the design process. We then identified design challenges and corresponding strategies in DH from design professionals. We conclude this paper with a proposed framework for a human-centered DH design process, including design challenges and strategies.

2. Methodology

We used purposive sampling (Etikan et al., 2016) to conduct semi-structured interviews with DH designers until the saturation threshold was reached (Fusch and Ness, 2015). The study was approved by the Human Research Ethics Committee of Delft University of Technology in September 2021.

2.1. Participants recruitment

Using a snowballing recruiting method (Streeton et al., 2004), participants were recruited and interviewed between November and December 2021. The inclusion criteria were.

- Over 1 year of working experience
- Involved in at least one DH design-related project that applied HCD or user experience (UX) design approaches.
- English or Chinese speakers - related to the researchers' language skills.

In advance to the interview, participants were asked to think back on a significant DH design project they had been involved in and to share relevant project information (if applicable) with the interviewer (TW).

2.2. Procedure

An outline interview with semi-structured questions was developed

to discuss experiences and views of designers on how they addressed digital PEx in their design process (Appendix 1). The interview included several main questions, for example, 'Could you tell me more about the DH design project that you shared (e.g., design context, work distribution, design challenges)' and 'could you walk me through your design workflow on this project'? Each interview lasted between 1 and 2 h and was conducted in English or Chinese using online meeting software.

2.3. Analysis

All audio-recordings were transcribed, deidentified, and grammatically corrected where necessary to prepare for analysis. For conversations in Chinese, translations to English were made for quotes, codes, and themes. The deidentified transcriptions were imported into ATLAS.ti (Scientific Software Development GmbH; Version 22.1.0; 3475) for analysis. Data extraction focused on the following areas: 1) participants' demographics including gender, major, year of graduation, job title, work domains, work years, numbers of DH projects, company type, company size, and work location; 2) characteristics of self-reported DH design projects, such as design contexts, target users; 3) design processes, such as design phases, stages, activities, deliverables, and stakeholders involved; 4) design challenges and corresponding strategies. This study is part of a wider research initiative, and additional research conducted within the program will be presented in a forthcoming article. Besides, the detailed characteristics of the participating designers and of their self-reported DH design projects, as well as their perspectives on the differences and similarities between UX, patient experience (PEx), and digital PEx, between designing for healthcare and non-healthcare projects, were reported in a previous article (Wang et al., 2022c).

Following Braun and Clarke's six-phase thematic analysis method (Braun and Clarke, 2006), three coders participated in the entire iterative coding process to analyze the extracted data (Fig. 1). After data-familiarization, an initial coding scheme was developed by TW. Three sample transcriptions were used to code and modify the coding scheme, followed by a group discussion to resolve any discrepancies. Once consensus was achieved, the remaining 21 transcriptions were randomly assigned to three sets, each comprising seven transcripts. Each coder then independently coded one of these sets. Regular group meetings were scheduled to discuss any ambiguous or newly generated codes. The final, revised coding scheme can be found in Appendix 2. The entire coding process followed five coding techniques: 1) generating codes as close to the original texts as possible; 2) simplifying and clarifying the codes while keeping their original meanings in the texts; 3) using a structured way to formulate the codes (e.g., verb phrases, noun phrases); 4) combining similar codes to minimize the total number of codes; 5) using English codes to code Chinese texts; and 6) marking ambiguous and newly generated codes for later group discussions.

3. Results

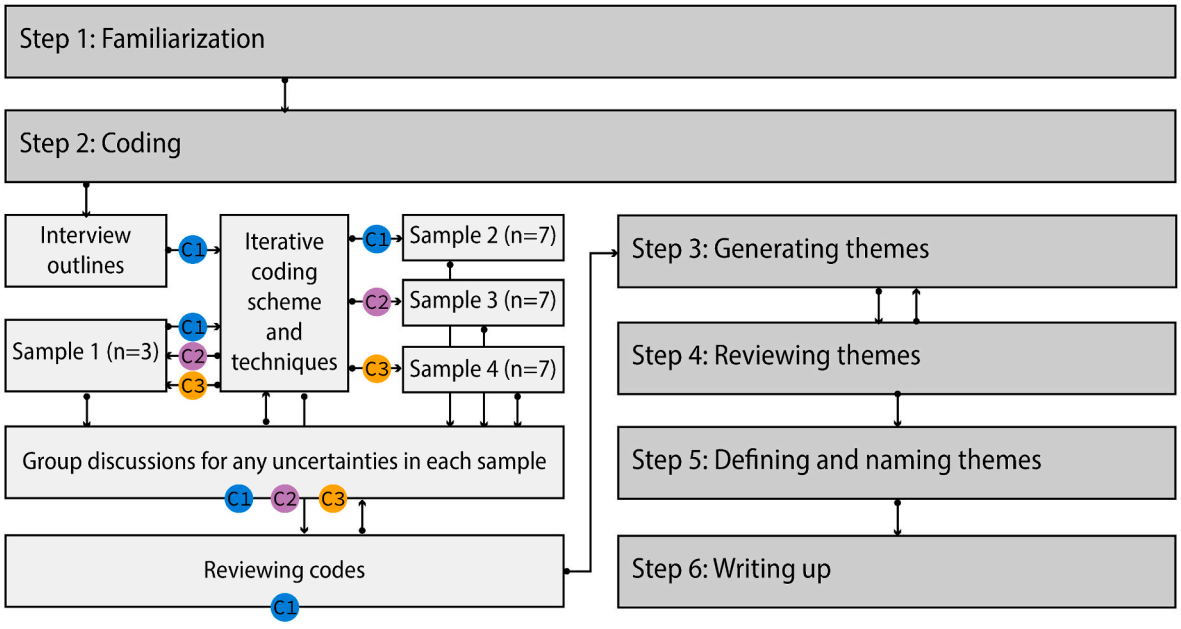
We conducted interviews with 24 international human centered or UX designers involved in creating DH solutions. Our research revealed four phases and eight stages in the DH design process. For each stage, we identified design activities, deliverables, and the involvement of different stakeholders. Furthermore, we identified twelve design challenges and their associated strategies that can impact the design process.

3.1. Participants

Table 1 presents the participant demographics. Most were women, had a master's degrees, underwent design education in the Netherlands, and graduated between 2005 and 2020. Their work experience varied from 1 to >16 years, averaging 5.5 years. Most of the reported DH design projects were conducted for large companies. See Appendix 3 for additional details about the participants' demographics.

3.2. Projects

Our findings show that designers are involved in diverse design contexts across the healthcare domain. Interviews with participants revealed a mix of digital health projects, showcasing the variety of



Notes:
1. C1: coder TW; C2: coder QS; C3: coder HZ;
2. Sample 1 includes 3 randomly selected transcriptions, the remaining 21 transcriptions were randomly divided into samples 2, 3, and 4, each containing7 transcriptions.

Fig. 1. Iterative coding process based on Braun and Clarke's six-phase thematic analysis method (Braun and Clarke, 2006).

Table 1
Description of study participants (N = 24).

Characteristics	n
Gender	
- Woman	18
- Man	6
Education degrees	
- Master's degree	20
- Bachelor's degree	2
- Doctoral degree	2
Education location	
- The Netherlands	16
- China	3
- The United States	3
- France	1
- Finland	1
Years of working experience	
- >5 years	10
- 1–2 years	8
- 3–5 years	6
Current company size	
- Working in large business (over 200 employees)	10
- Working in small business (less than 50 employees)	8
- Working in medium business (50–-200 employees)	4
- Working in academia.	2
Current work location	
- The Netherlands	9
- China	7
- The United States	2
- The United Kingdoms	2
- Canada	1
- Sweden	1
- Norway	1
- Spain	1
Project context	
- A large company (over 200 employees)	10
- A small company (less than 50 employees)	6
- A medium company (50–-200 employees)	4
- An academic context	4
Project location	
- The Netherlands	10
- China	6
- The United States	3
- The United Kingdoms	2
- Finland	1
- Spain	1
- India	1

healthcare services and healthcare issues. These projects (see appendix 4) can be broadly categorized as follows.

- Interaction Design (17/71%): creating user-friendly interfaces for websites and mobile apps, like migraine management and patient communication.
- Strategic Design (9/37.5%): developing new healthcare models and pathways, such as integrating future health visions into practical design frameworks.
- Product Design (3/12.5%): developing medical products, such as a device for respiratory disease screening.

Notably, some projects were categorized into more than one cluster because their application scopes were quite broad. Besides, healthcare issues addressed were primarily chronic conditions (15/62%), ranging from diabetes, migraine, sleep disorders, and hypertension to kidney cancer, breast cancer, strokes, mental health therapies, and neurological disorders. Acute medical conditions made up 4/17% of the focus, including surgeries, COVID-19, and respiratory diseases, while 5/21% dealt with broader health issues, including reproductive health and general wellness. More details of the project characteristics and design contexts can be found in a previous publication (Wang et al., 2022c).

3.3. Digital health design process

We identified eight stages in the DH design process which we grouped into four phases: (1) preparation, including clarifying requirements and limitations, and creating a project plan, (2) problem-thinking, including conducting desk or field research, and framing design problems (3) problem-solving, including generating and evaluating design concepts, and (4) implementation, including developing design solutions, and making market release and maintenance. Table 2 presents the phases and stages, and lists design activities, deliverables, and stakeholders for each stage, along with illustrative quotes.

3.3.1. Phase 1. preparation

Stage 1.1 Clarifying project requirements. Receiving the design task from internal or external clients often marks the beginning of a DH design project: "First, meet your clients; they will say what they would like to achieve [P11]." The inception of a DH design project can range from a vague design intuition (e.g., "a thought from daily life [P13]") to a broad design vision (e.g., "improve the PEx [P1]"), or it can be a specific design brief (e.g., "design a digital patient sheet [P18]"). It often follows a typical design process (e.g., "double diamond [P2]"). Design requirements (e.g., "design context [P24]"), resources (e.g., "investment [P13]"), and briefs (e.g., "project purposes [P18]") are typically clarified early on, considering public sector regulations and stakeholder interests and resources.

Stage 1.2 Creating a project plan. A plan gives stakeholders a comprehensive understanding of project complexity and provides a dialogue that breaks down divisions: "project management is your best friend [P3]" and it "needs to be looking at everything [P3]". Initially, this stage was infrequently mentioned by the participants in their workflows. However, on reflection on past projects, many acknowledged the need for "good project management [P22]", "a person who has the vision [P16]", "more structured and continuous inputs [P17]" from varied stakeholders, "making a holistic plan [P6]", and "knowing about how the process was going to be [P1]" from the beginning, if they were to run the project again. "A time plan is an important factor for managing the design process better [P10]". During this stage, typical tasks include building the team, managing time, allocating assignments, determining methodology, and setting milestones.

3.3.2. Phase 2. problem-thinking

Stage 2.1. Conducting desk or field research. This stage entails desk or field research to identify design problems and opportunities. "Interviews [P2]", "observations [P22]", "desk research [P10]", "literature research [P17]", and "co-creation [P20]" were commonly mentioned as methods to understand the context. Opinions varied regarding when and to what extent end-users should be involved; see more details in Section 3.4. Designers did not always follow rigid, step-by-step design processes such as conducting interviews or making patient journey maps. Sometimes, they chose to proceed based on their "design intuition [P18]". Representative "personas [P2]" and visualized "patient journeys [P16]" are common outputs.

Stage 2.2. Framing design problems. Insights from earlier stages aid in discovering user needs, framing design problems, and creating overarching design goals. These then guide the generation of solutions at later stages. Common techniques used to "interpret what people say and go beneath the surface of the thing [P5]" include "self-inquiry [P1]", "group discussion [P12]", and "co-creation [P20]". This leads to generating prioritized "problems [P9]" and unified "design goals [P18]".

3.3.3. Phase 3. problem-solving

Stage 3.1 Generating design concepts. In this stage, designers aim to provide a range of solutions to a clearly defined problem by seeking inspiration from different sources and co-designing with different people. This concept generation is typically iterative: "you begin by creating

Table 2
Design phases, stages, activities, deliverables, and involved stakeholders in the digital health design process.

Phases	Stages	Activities	Deliverables	Stakeholders	Illustrative quotes
1. Preparation	1.1 Clarifying requirements and limitations (n = 7; P1/2/10/11/14/18/19),	• Group discussions	• Project brief • (Re)design tasks	• Clients (e.g., purchasers, project managers). • Designers: design professionals, domain experts (e.g., supervisors). • Others: hospitals.	• I started with a project brief [P1]. • First, meet your clients; they will say what they would like to achieve [P11]. • We had a kick-off meeting for this project [P14].
	1.2 Developing a project plan (n = 7; P1/3/10/14/16/23/24)	• Division of work • Methods determination • Weekly alignment	• Research plan	• Clients (e.g., project managers, leaders) • Designers: design professionals, domain experts (e.g., quality groups).	• You have to make sure your quality management throughout the development process is well built up and well documented [P2]. • The initial part was fieldwork, so we created a research plan [P3]. • We initiated group discussions with developers to formulate the design scope [P19].
2. Problem-thinking	2.1 Conducting desk or field research (n = 24; P1-24)	• Interviews • Observations • Desk research (e.g., market research)] • Co-creation • Literature research • Other user research (e.g., context mapping) • Experiments • Patient profiling • Design intuition • Coding	• Pain points • Current patient journey • Personas • Theoretical framework • Existing solutions	• Users: patients, patients' family members, and health care providers. • Designers: design professionals, domain experts (e.g., doctors, nurses, marketers, other colleagues). • Others: hospitals, care homes, and communities.	• We spoke to clinicians to carry things out in reality [P9]. • I did literature research to understand the definition of patient experience [P17]. • We brought these things together in big workshops with 40–50 people [P20]. • We worked on creating a patient journey based on what the doctor said. And then we visualized the results to the patient representatives [P16].
	2.2 Framing design problems [n = 24; P1-24]	• Synthesis • Co-creation (e.g., workshop) • Self-inquiry • Group discussions • Prioritize problems and insights. • Filtering user needs	• Design insights • Design goals • Design needs • Research papers • Futuristic patient journeys • Service maps	• Designers: design professionals, domain experts (e.g., doctors, clinical partners, product managers, programmers) • Users: patients, healthcare providers	• Based on the patient and the expert interviews, where we learned a lot about the treatment and medical background, we defined design visions [P2]. • Our role as designers is to interpret what people say and go beneath the surface of the thing [P5]. • We created these design principles for the future that came out of these discussions in the workshops [P20].
3. Problem-solving	3.1 Generating design concepts [n = 22; P1-7/9/11–24]	• Brainstorm • Group discussions • Wireframes creation • Workshop • Industrial design • Visualization	• Design concepts (e.g., interface sketches) • Design directions • Use flow	• Designers: design professionals (e.g., supervisors, graphic, product, interaction and UX designers), domain experts (e.g., marketers, developers) • Users: patients, healthcare providers	• We did the wireframes. We have a graphic designer and product designer who designed the app [P5]. • We brainstormed and developed design concepts [P15].
	3.2 Evaluating design concepts (n = 18; 1–6/8–9/11/13–15/17–22/24)	• User test • Validation • Group discussions • Interviews • Questionnaires • Experiments • Cost evaluations • Usability tests (e.g., rapid prototyping and testing) • Market research (e.g., competitive analysis) • Prioritize concepts	• Prototypes • Storyboard • Design strategies • Purchase advice • Innovation roadmap • Feedback from patient family members • Advice on existing solutions	• Users: patient representatives, patient families, citizens, and healthcare providers. • Designers: design professionals, domain experts (e.g., doctors, managers, IT people, and marketers).	• We did a first proposal for the app prototype; we went back to users and tested it in two iteration cycles of improving small things [P2]. • I always do some concept or usability testing on different solutions with caregivers and patients [P8]. • We had to prioritize them (design concepts) based on the value for patients and the value for hospitals [P20].
4. Implementation	4.1 Developing design solutions (n = 9; P2/4–6/14/18–19/21–22)	• Programming • Hardware development • Visual design • Structural design • Proofing assembly	• Technical foundation • Graphics • Content • Design solutions	• Designers: design professionals (e.g., UX researchers and designers), domain experts (e.g., programmers, developers, engineers, and health care providers).	• A bit of back and forth between UX researcher and the programmer to finalize the app [P2]. • We have engineers who were going to code the APP [P5].

(*continued on next page*)

Table 2 (*continued*)

Phases	Stages	Activities	Deliverables	Stakeholders	Illustrative quotes
		• Technical assessment • Interview			• We were trying to start doing the technical foundation of the eye track with them (developers) [P21].
	4.2 Making market release and maintenance (n = 7; P2/5–6/18–19/21–22)	• Market release • Usage data monitoring • Onboarding patients • Lean startup methodology • Expert consultations	• Business model • Limited accessible on play store • Research reports	• Designers: design professionals, domain experts (e.g., marketers, IT people, specialists). • Users: invited users.	• The app is accessible on play store, but only for people who are invited; they can download it from play store [P2]. • We released the app, and then onboarded the patients [P5]. • After releasing the APP, we monitor system usage data [P18]. • This project was gone and failed, probably because the business model was not suitable [P19].

concepts, then check, test, and develop them thousands of times [P11].” Both “brainstorm [P15]” and “co-creation [P20]” are used to generate design ideas, and “wireframe [P2]” is used to refine these concepts.

Stage 3.2 Evaluating design concepts. Providing “evidence-based [P22]” and “validated [P23]” concepts are expected by clients, clinicians, and/or patients. Designers either perform “self-evaluation [P18]” based on pre-defined criteria or invite end-users and domain experts to do “usability tests [P8]”. More “tangible metrics [P5]” for user testing was suggested, and “continuous [P6]” user testing was noted for iterative design processes. “The value for patients and the value for hospitals [P20]” is used to prioritize design concepts. “Prototyping [P20]” served as a method to materialize concepts and is commonly used for evaluation.

3.3.4. *Phase 4. implementation*

Stage 4.1 Developing design solutions. This stage highlights the importance of “visual design [P2]” and “technical foundation [P21]”. To finalize the product, “a back-and-forth between the UX researcher and the programmer [P2]” was mentioned. Both “hardware and software development [P6]” can take place in this stage. This can be followed by another round of evaluation related to “technical issues [P18]”. Considerations for “system integration [P8]” are also crucial at this stage.

Stage 4.2 Making market release and maintenance. The last stage of the design process often involves market release (e.g., “released the app and onboarded the patients [P5]”) and its subsequent maintenance (e.g., “monitoring system usage data [P8]”). Some designers participated in creating and validating the “business model [P21]”, while others expressed dissatisfaction due to their projects failing because of an “unsuitable business model [P19]” or “poor supply chain [P6]”. Many projects had limited market release (e.g., “only people who are invited can download it [P2]”) and some did not even proceed to market release. In cases where there was no need for a redesign or product iteration, technologists and marketers took responsibility for “collecting user feedback [P6]” and maintenance. A common concern among designers was losing track of maintenance (e.g., not involved in the actual realization [P11]” or “don’t know what happened with that [P5]”). Some believed that “we would have to be involved again, but I don’t know when [P2]”.

Fig. 2 shows that almost all projects entail both problem-thinking and problem-solving phases. Only a small portion of projects in companies encompassed all four phases; the first or the last phase were mainly ignored. For projects in an academic context, the design processes mostly spanned the initial three phases. Most projects culminated in design concepts or prototypes, with only a handful of iterative projects launching their final designs, such as applications or wearable devices. A small number of designers were involved in the market release and maintenance stages.

Among our participants, there was a clear division of opinion about the differences and similarities between designing for patients and designing for healthy people. Some (n = 13/54%) argued there is a big difference, while others (n = 11/46%) believed that designing for patients and designing for healthy people are the same. The similarities and differences concern three aspects: design principles, user attributes, and design contexts (Wang et al., 2022c). Additionally, participants provided a range of responses about how they perceive user experience (UX), patient experience (PEx), and digital PEx. Their answers were mapped onto five dimensions: people, contexts, purposes, means, and usage scenarios, which were elaborated in a previous publication (Wang et al., 2022c). According to their understandings, the concepts of UX, PEx, and digital PEx can be distinguished between.

- designing for “specific" or "general" people: in contrast to PEx, which exclusively focuses on patients, UX aims for all users, such as patients and healthcare providers, that are involved in the entire service plan. Both of them refer to human-centered design; PEx focuses on patient-centered design, while UX relates to user-centered design.

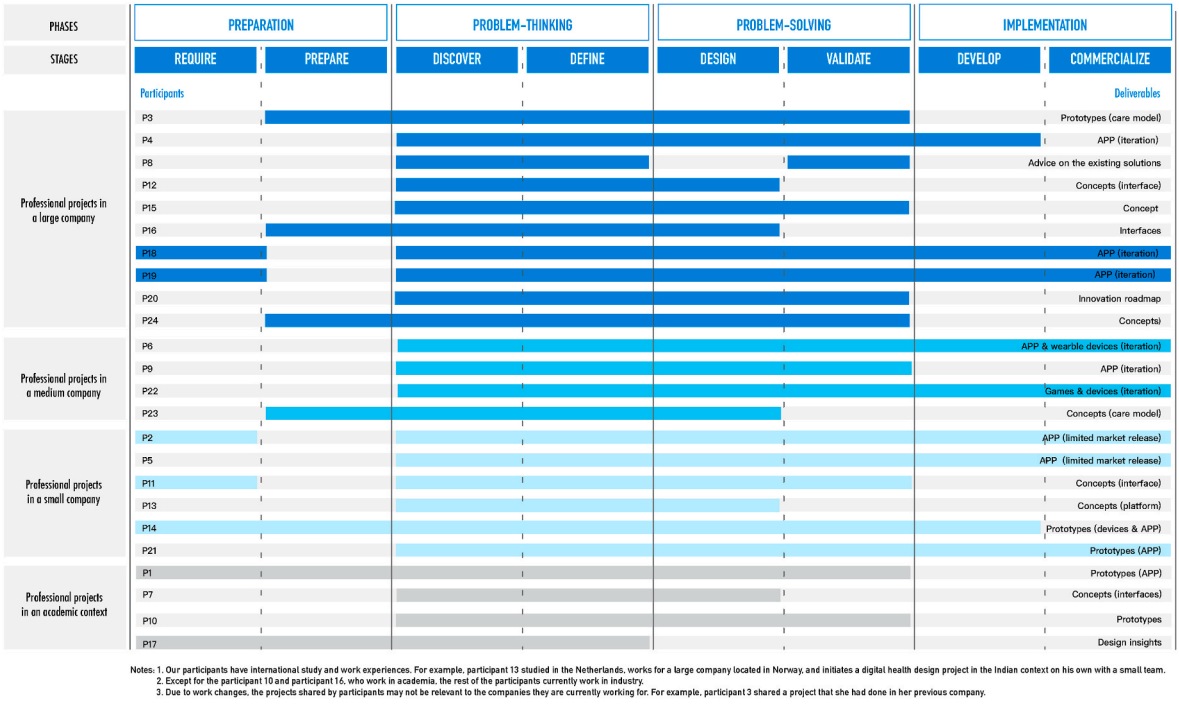


Fig. 2. Participants' design processes (i.e., involved design phases and stages mapping in terms of project types).

- designing for "continuous" or "momentary" contexts: (digital) PEx is considerably more continuous and permeates patients' everyday lives than UX, which is more concerned with momentary touchpoints. Due to the sensitivity and vulnerability of patients, the impact of human-computer interactions on (digital) PEx is greater than that on general UX.
- designing for "emotional" or "functional" purposes: (digital) PEx is far more emotionally loaded and is more influenced by patient-specific situations than UX. The former focuses more on patients' well-being; it is substantially more complex, intangible, and challenging to measure than the latter, which focuses more on overall system performance and can be evaluated easier.
- designing through "digital" or "hybrid" means: digital PEx is the digital version of the PEx. It highlights more human-technology relationships than general PEx in the traditional healthcare context. Notably, the design of digital health and non-digital health is not a binary opposition. To some extent, participants reported that digital PEx should be incorporated into the offline experience as well.
- designing for "concrete" or "vague" usage scenarios: the usage scenario of digital PEx is clearer than UX, as PEx often emphasizes a specific healthcare situation.

3.4. Participation of stakeholders throughout the digital health design process

3.4.1. Types of stakeholders

Table 2 shows a varied stakeholder group, including clients, designers (i.e., design professionals and domain experts), and users, being involved throughout the different phases and stages of the DH design process. Clients such as purchasers and managers typically hold high-level positions in hospitals, businesses, or the public sector. They often act as decision-makers in the design, purchase, implementation, and commercialization phases. UX designers, engineers, programmers, as well as medical, policy, and marketing experts often acted as design professionals or domain experts and were responsible for delivering designs. Two key user groups were identified: healthcare providers using DH systems to deliver care services, and healthcare receivers receiving these care services. These users can be either direct or indirect, depending on their degree of interaction with DH. They were often involved in the problem-thinking and problem-solving phases, especially during the fieldwork and user testing stages. Healthcare providers played varying roles in the design process. Some participated actively as clients or domain experts and were part of the design team, while others played passive or temporary roles as end-users or stakeholders. Patients often collaborated with designers as end-users. Moreover, while some stakeholder groups, such as insurance companies, did not actively participate in the design process, their potential influence on future collaborations was acknowledged and considered.

3.4.2. Necessity of patient involvement

There was some disagreement between participants about the necessity of involving patients in the design process. Most participants insisted that patient involvement was crucial for creating user-friendly solutions. They argued that insights drawn from the viewpoints of other stakeholders could lead to biased outcomes. For example, "knowing patients by talking with doctors cannot represent patients' perspectives; doctors transform all patients into one person; we should keep a certain distance from it [P16]". However, as it is often difficult and time-intensive to approach patients, some argued that it was more efficient to learn about patients from other accessible stakeholders who know the patients well, such as nurses, doctors, marketers, and patients' family members: "nurses can actually say a lot about the patients because they've been observing them every day [P13]." Nonetheless, some designers suggested that patient involvement may not be as significant for a business-to-business project, given that the final decision-makers were not the patients themselves. These designers believed that they "already possessed sufficient knowledge about patients through internal collaborators [P19]".

3.4.3. Sequence of user research

There were differing opinions among the participating designers about the order in which to involve healthcare professionals and patients in user research. Their arguments addressed time efficiency, resource availability, and design context. Some believed that speaking to doctors first and then involving patients could improve their work efficiency: "in the past, we saw lots of confusion and conflicts between the

insights of patients and care teams which delayed us from taking decisions and starting to create. Then we decided that we would prioritize care teams [P9]". However, others expressed concern that this approach could lead to bias and preconceived notions before involving patients: "If we (were to) go to the doctor and based on the doctor's answers, create an interview for the patients, then it would have made the decision more focused (on the doctor) [P16]." Additionally, some designers felt that the order of user research "shouldn't matter, as a researcher, you need to be independent, and you need to be without projection and prejudice [P11]". Some suggested that the determination of the user research order should be based on the end-users, design goals, and resource availability: "it depends on your end-users; you should understand your end-users' perspectives at first [P12]".

3.5. Design challenges and strategies in digital health

Based on the experiences shared by our participants we identified 12 challenges in DH design, which we classified into four categories: contextual, practical, managerial, and commercial challenges. In addition, we identified 38 strategies the participants mentioned when tackling DH design challenges. Table 3 presents our findings.

3.5.1. Contextual challenges

Contextual challenges refer to healthcare system challenges a designer should consider prior to fieldwork. Includes adapting to complexity, dealing with documentation, and attuning to restrictions.

Challenge 1. Adapting to complexity. The healthcare sector presents intricate scenarios impacted by multiple factors including social settings and individual health conditions. Creating DH solutions necessitates extensive knowledge and diligent efforts. As participants stated, "healthcare itself is pretty complicated [P7]", often involves "many stakeholders [P21]", refers to "many subdivided medical treatment scenarios [P18]", and requires more empathy to understand "certain disease [P2]". "The ownership of the platform, the severity of patients' conditions, and the frequency of usage [P18]" can vary significantly. This complexity requires designers to have a certain "level of knowledge [P17]" about the technology involved.

Challenge 2. Dealing with documentation. When designing for healthcare, "the ethical issue should be taken into more considerations [P7]". Many participants felt overwhelmed due to the "regulatory barriers [P13]" and "ethical component [P20]". Obtaining "approval [P3]" was time-consuming and required many efforts. Additionally, "data security [P10]" and "storing information [P5]" were big concerns.

Challenge 3. Attuning to restrictions (and coordinating design resources). Considering "the overall product time cycle to meet the time constraints [P6]" was a big challenge. Most solutions are built on top of small things instead of "from a bigger perspective [P8]", which often leads to a negative UX. Factors like "COVID-19 [P2]", and "longer feedback chain [P19]" delay the design process and "money and time constraints [P21]" force designers to "limit [P9]" user research. Additionally, many participants struggled to avoid overinvestment of time and energy and felt it was hard to "dig yourself out [P3]" and "decide on when to move forward [P10]".

Strategies to contextual challenges. To address these contextual challenges, designers recommended: 1) initiating the project with design research such as literature reviews and market analysis to "build context and knowledge [P23]" and therefore adapt to complexity; 2) preparing earlier for the required documents by "working closely with the legal team and ethics board [P3]" to deal with documentation; 3) improving project management and resource coordination to attune to restrictions and "lead the team (Melles et al., 2021)" through time planning, risk management, and utilization of advanced technologies.

3.5.2. Practical challenges

Practical challenges refer to the expected actions a designer should take when working in the field. Includes reaching agreements, involving

Table 3
Design challenges and strategies in DH.

Categories	Themes	Example quotes	Strategies
Contextual challenges	Adapting to complexity [n = 8; P2/4/5/7/9/17/18/21]	• If you design something for gardening, you can go and do gardening. So, it's easy to put yourself in the context. If it's a disease, maybe a bit more empathy is required [P2]. • I think it (the biggest challenge) is the level of knowledge that designers have about the technical back-end solutions of things [P17]. • There are many subdivided medical treatment scenarios [P18]	• Being familiar with the background information, such as conducting a literature review and market research [P18/23]
	Dealing with documentation [n = 13; P1/3/4/5/7/10/12/13/17/18/19/20/21]	• That (writing the protocol and applying the ethical approval) was painful … it took a long time [P3]. • (We) have to go through the regulatory barriers, that's going to be quite a challenging part of the design process [P13]. • There is a very strong ethical component because we're talking about these new technologies and how they'll influence the healthcare [P20].	• Involving legal team [P3]
	Attuning to restrictions [n = 16; P1/2/3/4/5/6/8/9/10/13/14/15/18/19/21/23]	• They (the clients) are experiencing massive delays in the clinical trials due to COVID-19 … and their inabilities [P2]. • The main challenge is to consider the overall product time cycle and to meet the time constraints [P6]. • Because we have money and time constraints, we don't talk to the patients much[P21].	• Project, time, team, and risk management [P1/2/3/6/16/24] • Coordinating resources, such as integrating healthcare systems and utilizing advanced technologies [P4/18/19]
Practical challenges	Reaching agreements [n = 10; P3/5/6/8/10/12/17/18/20/23]	• Then what's best for the patient is quite often not the best for the caregivers or the best for finance. So, it might be very expensive, or it might be not the most efficient for caregivers or for the planners. And at least in our hospital, there's nobody	• Empowering designers [P3] • Setting milestones and common goals [P6/18] • Group discussions for uncertainties [P24]

(continued on next page)

Table 3 (*continued*)

Categories	Themes	Example quotes	Strategies
		really high in the hierarchy who represents the patient [P8]. • The big puzzle is for nothing to slip away in between, or there's not so much overlap that people (team members) feel like they're in each other's way [P22]. • I would say that from a design team standpoint, the biggest conflict was really more about methodology. What's the best way to answer these questions? What are we really assuming? There were points where some people might have felt more strongly about certain ideas, or that this is what we needed to do [P23]. •	
	Involving end-users [n = 19; P1/3/5/6/7/8/12/13/14/16/17/18/19/20/21/22/23/24]	• Not all their mental space is there to help you at the moment they're ill or when they're dealing with a lot of stuff [P1]. • Managing all the stakeholders who don't really have anything to do early on is difficult [P3]. • The user doesn't always tell the truth [P7]. • Reaching out to the right people back in the design process who are available is a bit tricky [P13]. • We don't always have the information that crosses gender, different age groups, and different races, like it's truly diverse, making it difficult to define a digital patient experience or solution that considers everyone [P23]	• Utilizing advanced technology [P19] • Explaining everything [P3] • Knowing patients from other available people [P22] • Empathy [P2] • Understanding everything from desk research or literature review to inform conversations with stakeholders [P5] • Prioritizing design value [P9]
	Making design decisions [n = 15; P1/3/5/6/8/9/10/11/12/13/15/18/19/21/23]	• The challenge is to keep it (the design solution) personal, to make sure that everybody (each patient) feels heard [P1]. • Making sure we're designing these so that the user experience is equitable [P3].	• Designing equitable experience [P3] • Systematic view, considering design vision, clients' inputs, and design principles [P2/20] • Setting a timeline [P10]

Table 3 (*continued*)

Categories	Themes	Example quotes	Strategies
		• What's best for the patient is quite often not what's best for the caregivers or finances [P8]. • It's hard to fit the technology into users' daily lives [P10]. • What the client thinks is needed and what the actual user needs is often different [P11].	• Involving decision-makers in the process [P17] • Group discussions on conflicts [P20] • Empathy [P13]
Managerial challenges	Managing relations [n = 7; P2/3/5/7/9/15/24]	• We don't really have a very good relationship with the company (i.e., client) anymore [P2]. • Everybody (i.e., stakeholders) wants their own thing, and I have to give a balanced advice, which always means that somebody will be angry or at least unhappy with you [P8]. • We did it this way because we felt a lot of pressure from professional researchers [P24].	• Being in no direct contact with the client [P5]. • Involving people who can play active actors in managing relations with others [P3] • Placing domain experts in the right place [P23]
	Building understanding [n = 7; P1/2/5/10/17/20/24]	• There's always a gap between what people say they want and what actually happens in practice [P5]. • It's a little bit tricky, and you need to be in the patient's position and understand what it feels like for them [P13] • There was a big misunderstanding; the reason being that the same word meant different things to different people [P16]. • (It was difficult to) facilitate a discussion by expressing what the needs are of different users and why, and together coming to a consensus [P17].	• Empathy [P2/13] • Group discussions on conflicts [P10/20] • Making things tangible and visualizable [P1/10/23] • Writing full sentences when explaining things [P24]
	Communicating design value [n = 14; P2/3/5/6/7/8/9/10/12/14/17/18/23/24]	• From my perspective, what design could do is just make slight interventions, slight changes, slight improvements; that's already very difficult [P7] • I had to work with them quite a lot for them to understand	• Making things tangible and visualizable [P10/24]

(*continued on next page*)

Table 3 (*continued*)

Categories	Themes	Example quotes	Strategies
		what design research is and how you execute it [P17]. • The hardest (is) to convince others about taking a human-centered approach [P23].	
Commercial challenges	Providing evidence [n = 7; P5/8/11/17/20/22/23]	• It's hard to define whether they feel better because of the app itself or because it created a better connection with their HCP [P5]. • In the lab, everything went well. But in the actual validation study, it was horrible; it didn't work [P11]. • Everything needs to be evidence-based; publish research papers before trying something. I think that's a big thing to overcome because we need to speed up innovation [P20].	• Telling real user stories, reporting quantitative data, showing design expertise, and proving solutions [P18] • Conducting systematic reviews [P5/22] • Making things testable [P20] • Standardizing evaluations and providing tangible metrics [P5] • Conducting concept or usability tests [P8]
	Implementing solutions [n = 12; P2/4/5/6/8/11/14/15/16/17/18/20]	• There was a low usage rate for the software due to poor hardware development, so we're looking for new suppliers [P6]. • Which is quite frustrating in a sense because you went from zero to this developed project and everything depends on the client, so you can't really do anything about it [P5]. • The exchange of data between different solutions is really a big problem … (The suppliers) don't allow other APPs to integrate with them [P8]. • It's hard to implement the solution [P15]. • They (patients) are so stuck in their ways because they've always done it that way[P17].	• Involving programming experts [P2] • Convincing people who are most against the solution to use it first [P5] • Involving decision-makers in the process [P17] • Conducting user training when introducing new technology [P6]
	Establishing business models [n = 8; p5/8/10/13/15/18/19/21]	• Because at the end of the day, they're (clients) the ones who have to sign off on whatever it is that we're creating [P2]. • It's difficult financially because you're under contract for reimbursement. It's not so much about the value of the services. it's what your budget holders are willing to reimburse [P3]. • It (the market release) depends on the client; you can't really do anything about it [P5]. • The biggest unknown for us is how the money is going to come to the company [P13].	• Working with multiple budget holders [P3] • Involving hospitals first then insurance companies [P13]

end-users, and making design decisions.

Challenge 4. Reaching agreements (with and between collaborators). Collaborating across varied parties often leads to "conflicts and different points of view [P9]". This is especially the case between groups like the "product manager and interaction designer [P18]" and "IT people and design advisers [P8]", due to different expectations and perspectives. Some designers complained that HCPs believed more in "scientific methods [P23]" and felt that designers were "intruding [P5]" into the medical field. For designers, introducing a "human-centered approach [P23]" to non-design domain experts was also difficult. Some designers felt "fully patient-centered [P9]" was unrealistic and "user-centered design [P6]" was more like a superficial slogan. Additionally, "what everyone would have done [P16]" is not always clear. Creating a smooth process among different job roles to make sure "nothing slips away in between and not too much overlap [P22]" was a big puzzle. It was sometimes unclear what the roles and responsibilities were in the design process, the people who took on the role might change.

Challenge 5. Involving end-users (and uncovering real needs). Involving sufficient end-users is challenging due to "time [P10]" and resource constraints, privacy issues, and sensitivity of subjects. It required "extra application (for human resources) [P19]" and sometimes designers were even "unable to [P12]" or "not allowed to [P1]" contact patients. Furthermore, engaging end-users "in the right phases [P3]" was difficult and "people are becoming more protective of their time [P3]". If they get involved too early, they "don't really have anything to work on [P3]". However, they cannot be "well exposed and brought into [P1]" the entire context if they join too late. Approaching vulnerable and self-protective end-users effectively was tricky due to "sensitive topics [P7]" and "personal concerns [P12]". For example, "COVID-19 infection could be a sensitive topic [P10]" for some people at a certain time. When co-creating with patients, designers "have to be very careful [P6]" to make them "feel that their data is secured and protected [P10]", and "sharp on when to ask who [P1]" in terms of their health conditions. Patients do not always have the 'mental space' to help designers "when they're ill or when they're dealing with a lot of stuff [P1]". Additionally, "it's hard to recognize their (patients') preferences and needs [P10]" given "the user doesn't always tell the truth [P7]" and some of them even "don't know their real needs [P7]".

Challenge 6. Making design decisions. Balancing diverse stakeholder needs with real-world applicability presents a significant challenge in designing "user-friendly [P14]" DH. As one designer stated, "what's best for the patient is quite often not what's best for the caregivers or finances [P8]." This balancing act often creates a "struggle [P23]" in decision-making, such as when "immediate [P12]" patient needs in teleconsultation conflict with doctors' capabilities. Providing "equitable [P3]" UX was recommended but not easy. "We, as hospitals, always choose what's best for caregivers and planners over what's best

for patients [P8]", said one designer. Clients, representing the involved companies, driven by "money (i.e., profits) [P5]", have "a bigger influence [P19]" on decisions, which can diverge from "actual user needs [P11]". Good decision-making often needs "balance between the technology, users, and business [P13]", however, "utilizing technology to meet users' actual needs and seamlessly integrate it into their daily lives [P10]" was difficult.

Strategies to practical challenges. Participants employed various strategies to tackle the practical challenges encountered. 1) Designers should be "empowered [P3]" to choose the appropriate design methods and "make infographics from the research [P8]" to communicate visually and inclusively to reach agreements with diverse collaborators. 2) Designers also suggested using "desk research or literature reviews to inform our conversations with the nurses and with the patients [P5]". Caregivers and family members can help involve vulnerable patients (e.g., dementia, children). Moreover, empathy is often required "to be in the patient's position and understand how it feels for them [P13]". 3) To make a better design decision, designers should "make an educated guess [P13]" based on the defined design vision, client inputs, and design principles. To do so, "you always need to design with a systemic view [P20]", which means surfacing different perspectives, facilitating discussions on conflicts, and designing equitable experiences for involved stakeholder groups.

3.5.3. Managerial challenges

Managerial challenges refer to the collaborative atmosphere a designer should create throughout the whole design process. Includes managing relations, building understanding, and communicating design value.

Challenge 7. Managing relations. As one designer highlighted, "everybody wants their own thing, and I have to give a balanced advice, which always means that somebody will be angry or at least unhappy with you [P8]". Some participants voiced frustrations with clients who "didn't like our suggestions [P5]" or "didn't have a very good relationship [P2]" with them anymore. Designers noted doctors' skepticism, feeling they "don't necessarily believe in us [P5]" and "tend to trust their own experience over technology [P20]". There were also issues with IT personnel who routinely "thought that I was doing the wrong thing [P8]."

Challenge 8. Building understanding. Designers struggled to reach a consensus "by expressing what the needs of different users are and why [P17]". They noticed a dissonance between "what people say they want and what actually happens in practice [P5]". Additionally, "doctors and patients don't always speak the same language [P1]", and "different culture and language leads to different understanding on the same project [P15]". "The same word meant different things to different people [P16]", such as 'prototype'. Besides, it was difficult to "generalize and scale [P5]" individual findings to a broader population due to methodological limitations or personal differences.

Challenge 9. Communicating value. Designers seek to "communicate the importance of use-centered design [P6]" and "show your real value to your clients [P12]". However, practical constraints made it impossible to serve "100% of the population [P9]" or "cannot bring more surgeons to the hospitals [P9]". As one designer put it, the role of design was largely to introduce "slight interventions, slight changes, and slight improvements [P7]". Therefore, clarifying "what design research is and how you execute it [P17]" and "finding a way to tell that story [P3]" became essential.

Strategies to managerial challenges. 1) To manage relations with multiple stakeholders, "positioning them (stakeholders) as the experts seems to have been what really shifted things [P23]". Furthermore, the role of coordinators and bridging various stakeholders proved useful: "they (coordinators) know how to make things happen because they're very well connected and organized [P3]". Some found that "not being in direct contact with the client [P5]" allowed for more freedom. 2) To build understanding, some designers suggested "making things tangible [P1]" and "visualizing in some ways [P23]" to communicate between people who might not speak the same language. 3) Communicating design value means designers have to know how to "tell your story and write your story [P24]" effectively.

3.5.4. Commercial challenges

Commercial challenges refer to the business value a designer should add at the end of the design process. This includes providing evidence, implementing solutions, and establishing business models.

Challenge 10. Providing evidence. It is challenging to generate evidence and convince users to accept design solutions. For example, doctors "won't adopt new technology unless it has proven that it will improve their decisions or patient outcomes [P20]" while patients are often "stuck in the ways that they've always done it [P17]". "Making things testable in the early phase [P20]" and conducting "usability tests [P8]" with both healthcare providers and patients were suggested, though some noted: "in the lab, everything went well. But in the actual validation study, it was horrible [P11]."

Challenge 11. Implementing solutions. Designers sometime lose their 'voice' when working on commercial projects when it comes to implementation: "it depends on the client; you can't really do anything about it [P5]." As some designers stated, "it's hard to implement the solution [P15]" and "it's not easy to convince your clients [P18]". Additionally, they noted operational challenges associated with "the exchange of data between different solutions [P8]". Limited system integration sometimes increased designers' workloads, as one designer mentioned "we had to upload patient profiles manually [P4]."

Challenge 12. Establishing business models. "Implementing cutting-edge technology and establishing a comprehensive business model [P10]" was difficult. Designers were often left wondering, "you might want to create a great PEx, but who will pay for it [P5]?" They must consider factors such as "who impacts the final sales [P22]" and "what the budget holders are willing to reimburse [P3]", as they "sign off on whatever it is that we're creating [P2]". Sometimes the end user may no longer be the primary focus when "thinking about the business model again [P21]". However, establishing a viable business model is not easy; a participant stated "the biggest unknown for us is how the money is going to come to the company [P13]." Designers also "need to understand about insurance providers [P5]", and it depends on the location they are working on.

Strategies to commercial challenges. Commercialization requires stakeholder buy-in to the design and willingness to pay. 1) To provide evidence, designers believed that standardizing evaluations, providing tangible metrics, making things testable earlier, and conducting "a systematic literature review [P22]", will "show other people that this solution is much more friendly to use [P8]". Another strategy was "to identify who will be the largest opponents [P11]", because once they are convinced, the others will follow. Moreover, "providing user training [P6]" could enhance the acceptance of digital solutions. 2) To implement solutions and 3) establish business models, designers suggested "working with multiple budget holders [P2]" in the early design phase and "(involving the decision-makers) throughout the process [P17]".

4. Discussion

4.1. General findings

We explored the DH design process to reveal design challenges and identify potential strategies. Our results show that designers are engaged in various collaborative activities with multiple stakeholders and disciplines throughout the entire design process.

4.2. Design implications for digital health design

Based on our findings, in Fig. 3 we present our novel Digital Health Design (DHD) framework comprising the four design phases and eight

stages. We associated required stakeholders and possible design challenges with each phase and summarized eight adaptable strategies to address these challenges. Additionally, each phase depicts typical deliverables and design activities.

In an ideal situation, DH designers undertake a preparation phase by defining project requirements and constraints, as well as formulating project management plans together with clients, managers, and domain experts. Then, they move to the problem-thinking phase, identifying design problems, uncovering user needs through observing or talking with patients and healthcare providers, and defining design insights and goals. Next, they proceed to the problem-solving phase, where they start brainstorming or co-creation to develop design concepts and conduct user testing on small-scale prototypes. Finally, designers collaborate with programmers and marketers in the implementation phase to develop and launch the designs on the market. Occasionally, designers may also maintain or iterate the product post-release.

This process is non-linear, in line with many design process models like the double diamond innovation framework, human-centered design, and the design thinking process that emphasizes the iterative process (Council, 2019; IDEO.org, 2015; Hasso Plattner Institute of Design at Stanford, 2010). As illustrated in Fig. 3, designers can cycle through the entire process several times or iterate within, between, and across phases. Additionally, designers can begin or end at any stage depending on the specific context, and they have the flexibility to skip certain stages or alter the sequence of some stages based on their work preferences or project-specific circumstances.

Our study contributes to previous research in this field in many ways. First, the identified digital health process represents an extended double diamond process (see Fig. 3). Compared to the evolved Double Diamond framework (Melles et al., 2021; Council, 2019), which begins with understanding the problem and ends with testing out different solutions, our DHD framework begins with a preparation phase for clarifying project management, followed by problem-thinking and problem-solving phases, then concludes with an implementation phase for realizing commercial viability. Second, we recognized broader design challenges that refer to both design research and practice in varied digital health design projects. These provide the design community with a broader overview of which challenges they may face compared to our previous study (Groeneveld et al., 2018). Third, we identified many practical strategies to resolve challenges, which can help designers better equip themselves earlier in the process. Fourth, next to providing a general design process direction that could be also applied to other design domains, we have highlighted the specific activities, deliverables, and stakeholders involved in the DH design process at different design stages. While experience is intangible and volatile, an interactive DH solution is tangible and a mass-produced piece of technology (Cafazzo and St-Cyr, 2012). The way we design the digital PEx in healthcare determines how people will experience it. We believe that with the new DHD framework, designers are empowered to manage their DH design process more efficiently. Fifth, we uncovered designers' understandings of UX, PEx, and digital PEx, which partially align with the comparison of the academic definitions of these concepts. For instance, UX is regarded as "a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service" (Bolton et al., 2018; Jokela et al., 2003), PEx is defined as "the sum of all interactions, shaped by an organization's culture, that influence patient perceptions, across the continuum of care" by the Beryl Institute (The Beryl Institute, 2021), and digital PEx is defined as "the sum of all interactions, affected by a patient's behavioral determinants, framed by digital technologies, and shaped by organizational culture, that influence patient perceptions across the continuum of care channeling digital health" in our previous publication (Wang et al., 2022b). These definitions revealed that UX focuses more on general people's perceptions, which could be patients or healthcare providers, as long as they are the target users of the product, system, or service, while (digital) PEx targets patients in the context of healthcare. In addition, one of the biggest differences between PEx and digital PEx is the emphasis on digital technologies, which mediate all interactions between patients and other subjects in the healthcare system. We believe our findings on the similarities and differences of these concepts will help to build a common

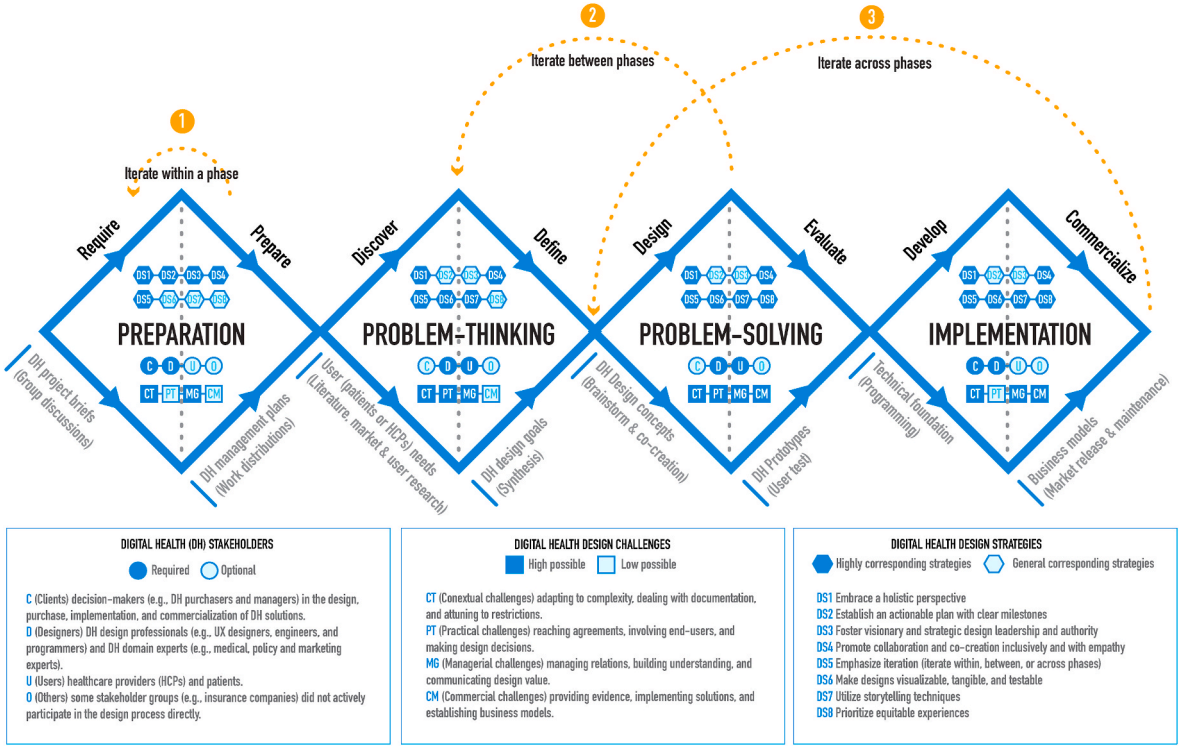


Fig. 3. The Digital Health Design (DHD) framework enables designers to manage the design process, engage stakeholders, deal with design challenges, and seek out design strategies for improving the digital PEx (based on the evolved Double Diamond framework (Melles et al., 2021; Council, 2019)).

understanding of them across interdisciplinary collaborators, bring their attention to the varied elaborations on these concepts, and therefore reduce misunderstandings.

4.3. Overthinking or overlooking the preparation and implementation stages?

Most designers felt the processes of their DH design were in many ways similar to the typical design process in other domains; only some specific design activities such as applying for ethical approval were identified as different across domains. This aligns with findings of a previous study (Eckert et al., 2004) which highlighted subtle differences in the design processes across domains. Almost all participants shared the problem-thinking and problem-solving phases in their design processes, while less than half discussed the preparation and implementation phases. We hypothesize that some designers undertook but overlooked preparatory tasks, seeing them as basic project components as this may have been primarily conducted by project managers as described in a previous study (Kleinsmann et al., 2015). Other studies indicate that the design process normally begins with the sales and marketing teams who recognize design needs (Clarkson and Eckert, 2010), and stress the need for coherent, assessable plans early on for process efficiency (Eckert and Clarkson, 2003; Dixon-Woods et al., 2012) and multi-dimension project management, such as process management, personnel management, and risk management (Clarkson and Eckert, 2010).

Although we did not count the duration of each phase, design stages like fieldwork often consume more time than others, like problem framing. We assume that the perceived significance of each design stage might relate to time allocated by designers. Duration, however, does not equate to significance. A phase requiring a longer time and engaging more stakeholders may encounter more design obstacles and require greater design efforts. We found most projects end with generating design concepts or prototypes. The transition from conceptualization to implementation stage was often obstructed by a variety of challenges and resource constraints. In contrast to designers working in small or medium-sized businesses, fewer working in larger businesses reported the implementation stage. We hypothesize that this may be attributed to the highly distributed nature of work in larger companies, where designers are accountable for a particular aspect of the design process rather than the entire process. We believe that designers' characteristics and project contexts significantly affect the design process.

4.4. When and who to involve in the design process?

Our findings regarding stakeholder groups align with human factors/ergonomics research (Dul et al., 2012) identifying decision-makers, system experts, actors, and influencers as the key groups. We show that truly patient-centric design is unlikely in the real world, given the involvement of multiple parties and their varying viewpoints. As human factors and ergonomics (Dul et al., 2012) indicated, system experts and decision-makers are more influential in the design process than actors. We found that clinical outcomes and business achievements were commonly valued more than user experiences. However, the cornerstone of effective DH design lies in a thorough and accurate understanding of both "user reality" and "clinical reality" (Cornet et al., 2019), meeting the needs of both care providers and receivers (Martin et al., 2005). Designing for human experiences requires prioritizing patient and user experience goals equally with process and clinical goals (Bate and Robert, 2006).

Patients and healthcare providers were the most common groups involved in the design process, acting as either domain experts or end-users. When acting as end-users, they were involved during fieldwork and user testing, aligning with a prior study (Martin et al., 2005) that user needs are usually identified during the design and evaluation phases. However, when involved as domain experts, it was less clear when to involve them and what they could contribute. Though some studies (Martin et al., 2005; de Wit et al., 2019) support patient involvement throughout the design process, our findings indicate that designers' opinions vary. Some advocate directly involving patients to improve their experiences, while others find that patient insights can be feasibly and efficiently gained from alternate sources. We believe that when aiming to improve the digital patient experience, patients should, where possible, be involved directly to uncover their real needs. However, in situations where resources are limited, gathering patient insights from alternate sources is practical. To minimize bias and ensure data saturation, we recommend relying on multiple sources, such as literature reviews and market research. There is no one-size-fits-all answer to stakeholder involvement, but we advocate designers actively engaging them in all stages of the project. Managers should lead the preparation phase, initiate relationships and create a holistic plan. Managers or designers should engage and enable clients to make informed decisions. Furthermore, domain experts should be involved, at least during the problem-thinking, problem-solving, and implementation phases to ensure relevant questions are asked and answered. Establishing a more defined distribution of responsibilities and meticulous planning will lead to smoother project progression.

4.5. Design challenges in digital health: similarities versus differences?

Our results revealed twelve distinct design challenges, some unique to DH design. These findings align with the previous study (Groeneveld et al., 2018) detailing challenges for design researchers in healthcare, indicating the shared hurdles among healthcare design context. Notably, the challenges we identified in this study only pertain to the obstacles that impede the design process, not the broader healthcare issues that designers seek to address through their design solutions. We show that some challenges, such as adapting to complexity and dealing with documentation, are more specific or demanding to DH design projects, while others, such as attuning to restrictions, are common or universal in general design projects. Restrictions, such as time, cost and resources constraints are prevalent in many design processes; these are not exclusive to digital health (Eckert et al., 2004). However, we believe that dealing with documentation can be more difficult, since the design of digital health often requires more ethical considerations for involving stakeholders and implementing solutions. These include issues such as limited access to patients due to ethical issues (Paulovich, 2015) and privacy and security concerns emerging from digitalization of healthcare (Cummins and Schuller, 2020). Furthermore, we discovered that practical and commercial challenges were often associated with specific design phases, while contextual and managerial challenges were often present throughout the entire design process. As an illustration, providing evidence was typically a requirement towards the validation phase, whereas managing relationships was an ongoing necessity in the design process. It is worth noting that challenges can be interrelated, with one possibly exacerbating another, or conversely, addressing one can alleviate another. For instance, poor project management could lead to late design accidents, unrealistic expectations, or a lag in technical innovation (Clarkson and Eckert, 2010). Project ownership and role responsibilities can also impact the challenges faced by designers. Self-initiated project designers often grapple more with commercial challenges, whereas designers in large corporations assigned to specific project aspects may experience lesser commercial pressures due to the structured work distribution in such environments.

Developing digital health products often requires interdisciplinary work (Pagliari, 2007) and involves multiple stakeholders (Lupton, 2017), often leading to challenges like reaching agreements, building understanding, communicating value, making decisions, and providing evidence. In healthcare design, interdisciplinarity can be intractable because the involved parties have diverse interests, values, and epistemologies across multiple fields (Bauer, 1990; Hose et al., 2023), as well as distinct ways of working, thinking, and communicating about design

(Clarkson and Eckert, 2010). An illustrative example is the tension between the slow process of evidence-based clinical trials and the expected rapid pace of innovation in the real business world. With fast technical development and fierce international competition (Clarkson and Eckert, 2010), the need to design better digital health products becomes paramount. However, the rapid pace of innovation may raise safety concerns due to the lack of quality and evidence-based research (Cummins and Schuller, 2020; Patrick et al., 2016). It can also create difficulties for non-designers to feel assured of the design process and quantify the design quality (Commission, 2014). Stakeholders in healthcare have myriad, often conflicting goals, such as profitability, convenience, and patients-centricity (Porter, 2010). Consequently, the perspectives of end users often differ from or are opposite to those of other stakeholders (Martin et al., 2005), implying that the support of one stakeholder group may risk alienating another (Dixon-Woods et al., 2012).

4.6. Design strategies in digital health: challenges versus opportunities?

To solve these challenges, our participants shared differing design strategies, grouped into eight themes. We found that some were mentioned for solving multiple challenges, while others were directed at solving a specific challenge. Challenges and opportunities are essentially two faces of the same coin in DH design. Challenges represent the hurdles that hinder seamless design, while strategies can lead to a successful design outcome. For example, time restrictions are sometimes both a challenge and an opportunity, causing designers' stress while, at the same time, serving as a motivator to increase work productivity. Therefore, it is beneficial to embrace clear constraints like cost limitations as these often fuel creative thinking (Commission, 2014). Additionally, we discovered that some strategies are difficult to execute and therefore, challenging to implement. For instance, although effectively involving, communicating, and aligning with stakeholders are suggested, achieving these goals can prove challenging, as varied stakeholder goals can lead to divergent approaches and slow performance improvement (Porter, 2010). While aligning the interests of multiple parties can take time and energy, it is more likely to ensure the sustainability of the solutions (Dixon-Woods et al., 2012).

We found that some strategies, such as visualization, are a core design competence, whereas others originate from the broader knowledge of other disciplines, such as project management. Certain strategies pertain to flexible mindsets, while others correspond to technical skills. For example, some participants believed that design thinking, including systematic view and empathy, was valuable for addressing many challenges like involving stakeholders and building understanding. Skills that make things tangible, testable, and visualizable were useful for building understanding and communicating design value. Moreover, empathy equips designers to understand the necessary limitations and context (Commission, 2014), and storytelling can help reveal patients' daily lives (Bate and Robert, 2006). Visionary and strategic leadership with strong links to external stakeholders can effectively handle managerial challenges (McInnes et al., 2015). Nevertheless, this is typically determined by the organization's top tiers (Commission, 2014). Designers need to be empowered to showcase their expertise.

4.7. Limitations

The first limitation is that due to the qualitative nature, some challenges or design stages that participants experienced but did not mention during interviews may have been missed. Therefore, the quantitative information may not fully reflect the actual situations. However, the use of semi-structured and open-ended questions enabled participants to freely discuss their work and associated challenges (Martin et al., 2012). The second arises from the complexity of healthcare challenges; this study may not have effectively revealed design strategies to solve them. Some proposed strategies were based on individual experiences and may lack sufficient evidence, but recognizing these issues is the first step towards addressing them in future research (Dixon-Woods et al., 2012).

4.8. Future research

A number of aspects should be explored more deeply. First, designers' attributes, such as their educational qualifications and job responsibilities, as well as contextual factors surrounding projects, such as project ownership and location, may affect their design processes, the types and levels of challenges they encounter, as well as the specific strategies and skills they would use. Future research could investigate the interrelationships between designers' characteristics and their design processes, challenges encountered, and preferred strategies. Second, the duration of each stage can impact how designers perceive its significance, so, investigating the time spent on each phase would add value. Third, our study revealed debates over when and whom to involve during the design process. Understanding the implications of involving, or excluding, specific stakeholder groups could be valuable, especially in resource-limited situations. Fourth, we believe that a predetermined allocation of work and a comprehensive plan would facilitate project management, so additional research is required to identify steps, methods, and criteria for creating a more effective industry design plan. Fifth, we discovered that clients played an important role in deciding what to design and how to implement it. However, it is unclear how to involve them more effectively in the design process to reduce their prejudiced expectations and establish shared goals with other stakeholders. Last, some strategies identified during our study were not tailored to address specific challenges. Therefore, we suggest that future research focus on exploring targeted strategies and presenting evidence to address each challenge identified in this study.

5. Conclusions

In this paper, we mapped the process related to design, redesign, and continuous improvement processes in digital health in eight stages and grouped them in four phases: preparation, problem-thinking, problem-solving, and implementation. We also identified twelve challenges and classified them in four categories: contextual, practical, managerial, and commercial challenges. Furthermore, we outlined eight corresponding strategies, recommended by the participants, to address each challenge type. Finally, we created a framework including design deliverables, activities, involved stakeholders, design challenges, and related design strategies for each design stage. The DHD framework not only aids designers in understanding the design practices in the healthcare industry but also guides them when managing their DH design processes and improving the digital PEx.

CRediT authorship contribution statement

Tingting Wang: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Haiou Zhu:** Data curation, Formal analysis, Methodology, Writing – review & editing, Validation. **Shuxian Qian:** Data curation, Formal analysis, Methodology, Writing – review & editing, Validation. **Guido Giunti:** Methodology, Resources, Supervision, Writing – review & editing. **Richard Goossens:** Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Marijke Melles:** Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 2. Coding Scheme 27022024

Categories	Themes and Codes
1. Design process	1.1. Preparation phase 1.1.1. Clarifying project requirements 1.1.2. Creating a project plan. 1.2. Problem-thinking phase 1.2.1. Conducting desk or field research 1.2.2. Framing design problems. 1.3. Problem-solving phase 1.3.1. Generating design concepts 1.3.2. Evaluating design concepts. 1.4. Implementation phase 1.4.1. Developing design solutions 1.4.2. Making market release and maintenance.
2. Design challenges	2.1. Contextual challenges refer to healthcare system challenges a designer should consider prior to fieldwork. 2.1.1. Adapting to complexity 2.1.2. Dealing with documentation 2.1.3. Attuning to restrictions. 2.2. Practical challenges refer to the expected actions a designer should take when working in the field. 2.2.1. Reaching agreements 2.2.2. Involving end-users 2.2.3. Making design decisions. 2.3. Managerial challenges refer to the collaborative atmosphere a designer should create throughout the whole design process. 2.3.1. Managing relations 2.3.2. Building understanding 2.3.3. Communicating design value. 2.4. Commercial challenges refer to the business value a designer should add at the end of the design process. 2.4.1. Providing evidence 2.4.2. Implementing solutions 2.4.3. Establishing business models.
3. Design strategies	3.1. Embrace a holistic perspective: adopt a systematic design perspective that considers all contextual factors at the beginning through literature reviews and market analyses. 3.2. Establish an actionable plan with clear milestones: outline structuring, adjustable, and measurable steps to guide the design process, track progress effectively, and frequently reflect on the project management. 3.3. Foster visionary and strategic design leadership and authority: encourage design thinking and empower designers, ensuring design approaches align with long-term goals. 3.4. Promote collaboration and co-creation inclusively and with empathy: respect experts and empathize with users inclusively, encouraging collaborative efforts and shared creation. 3.5. Emphasize iteration (iterate within, between, or across phases): embrace an iterative design process that allows for continuous improvement and refinement. 3.6. Make designs visualizable, tangible, and testable: communicate visually and make things tangible and testable to gather feedback and validate ideas. 3.7. Utilize storytelling techniques: incorporate storytelling elements to effectively communicate concepts, engage users emotionally, and convey the intended message. 3.8. Prioritize equitable experiences: ensure that the design process and resulting experiences are inclusive and fair, considering diverse user needs and promoting equal opportunities for all.

Appendix 3. Participants Demographics 27022024

Num.	Education background	Job title	Work domains	Work years	Numbers of involved DH projects	Types of company
P1	Integrated product design (MSc, 2019)	Design researcher	Social innovation design (not work in healthcare area anymore)	2 years	1 (in an academic context)	Design (small)
P2	Integrated product design (medisign specialization, MSc, 2018)	senior industrial designer	UX design and design management	3 years	5 (professional projects)	Design (small)
P3	Interdisciplinary design (MSc, 2010)	Design Lead measuring experiences	Patient experience transformation	10 years	10 (big professional projects)	Hospital & health care (large)
P4	Digital Arts (BA, 2005)	User experience designer	User experience design, product design for medical devices/products (move in the field of healthcare design)	16 years	1 (ongoing professional project)	Design and manufacture of personal healthcare products (large)
P5	Sustainable design & innovation management (MSc, 2017)	research and design	Help medical related company to develop products (move in the field of healthcare design)	6 years	4 (professional projects and a couple of others)	Design (the digital health product house) (small)
P6	Integrated product design (MSc, 2020)	design researcher	Healthcare product development, including brain-computer interface, Brain diseases and sleeping disorder	1 year	3 (in an academic context) + 3 (professional projects)	Electrical & Electronic Manufacturing (medium)

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Num.	Education background	Job title	Work domains	Work years	Numbers of involved DH projects	Types of company
P7	integrated product design (medisign specialization) (MSc, 2020)	product design engineer	Product design engineering (not work in the healthcare area anymore).	1 year	3 (in an academic context)	Electrical & Electronic Manufacturing (large)
P8	design for interaction (MSc, 2014)	eHealth advisor	Look for and implement existing solutions from different suppliers for the hospitals.	9 years	3 (big professional projects)	Hospital & Health Care (large)
P9	industrial design engineer (MSc, 2013)	Head of Design	Everything from user research to final design delivery.	10 years	more than 200	Hospital & Health Care (medium)
P10	strategic product design (MSc, 2020)	Lab administrator, researcher	Manage VR and carpentry labs and responsible for course design (not work in the healthcare area anymore, but plan to go back).	1 year	1 (in an academic context)	University (large)
P11	integrated product design (MSc, 2016)	Healthcare designer/ engineer	Translate medical research into products and services	8 years	5 (professional projects)	Design (small)
P12	Design for interaction (Meng, 2019)	UX designer	ehealth platform for psychological therapists	3 years	2 (in an academic context) + 1 (professional project)	Internet (large)
P13	integrated product design (MSc, 2019)	Industrial designer	Work in the intersection of education and healthcare	2 years	3 (professional projects)	Medical device (large)
P14	Product design (Beng, 2017)	Industrial designer	Household medical examination equipment	4 years	9 (professional projects)	Medical device (small)
P15	Strategic product design (MSc, 2019)	service designer	Digital tool for clinics and health professionals	2 years	2 (professional projects)	Hospital & Health Care (large)
P16	Information technology (PhD, 2019)	Postdoctoral Researcher and lecturer	Human computer interaction and interaction design lecturer in university	2 years	4 (professional projects)	University (large)
P17	Design for interaction (Meng, 2018)	service designer,	Work in health-related government projects on digitizing the interactive justice system	3 years	3 (professional projects)	Design (small)
P18	interaction and experience design (MA, 2019)	UX designer	Healthcare design (move in the field of healthcare design)	2 years	2 (small professional projects) and 1 (in an academic context)	Internet (large)
P19	Design for interaction (Meng, 2017)	interaction designer	Design for digital and non-digital healthcare service or system	4 years	8 (professional projects)	Hospital & Health Care (large)
P20	Design for interaction (MSc, 2014)	Strategic Design Lead	Build new ehealth solutions with clients and think about remote solutions	8 years	10 (professional projects from a strategic level)	Experience Consultancy (Information Technology & Services) (large)
P21	Design for interaction (medisign) (MSc, 2017)	Design strategist & market researchers (healthcare)	Innovation consultation in healthcare industry	5 years	3 (professional projects)	Management Consulting (small)
P22	Playful design for activation (PhD, 2014)	CEO/Founder	Product service system for people with late-stage dementia	12 years	1 (big professional project)	Hospital & Health Care (medium)
P23	Strategic Innovation & Entrepreneurship (MBA, 2022)	Design Strategy Lead	Work on industrial product related healthcare	9 years	10 (professional projects, 3 are big and the restl are small)	Information Technology & Services (medium)
P24	Industrial design (MID, 2012)	Experience design lead (center for digital health)	Experience design for digital Health	10 years	50 (professional projects)	Hospital & Health Care (large)

Appendix 4. Projects Characteristics 27022024

Participants	Design context	Project duration and completeness.	Clients	Stakeholders	End-users	Team members	Self-identified roles
P1	Design a digital consultation platform considering technology, to improve the patient experience by enabling the empathic conversation between patients and doctors.	5 months (completed)	A project in an academic context that collaborates with an external hospital	Doctors, patients	Patients (type 1 diabetes)	Design and medical experts, design fellows, and medical students	Designer, creative facilitator, adviser, e. g., give advice to the hospital based on design research
P2	Design a mobile app, to explain the use of a device for people who having migraine and survey their experience in clinical trials.	21 months (ongoing)	A project at a small company that designs for an external company	Patients, medical experts	Patients (migraine)	(UX and visual) designers, programmers/ software engineers/ developers	Lead designer, project manager, e.g., responsible for user research and client contact
P3	Design a new model of care, to replace face-to-face hospital visits by	12 months (completed)	A self-developed	Clinical partners (physicians and nurses)	Pregnant women (pregnancy)	Project/product manager, innovation coordinator, user	Lead for the design discovery and fieldwork

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Participants	Design context	Project duration and completeness.	Clients	Stakeholders	End-users	Team members	Self-identified roles
	virtual visits for empowering women experiencing low-risk pregnancy.		project at a large company			researchers, designers (intern), finance people, and medical experts	
P4	Design a health care system, to encourage diabetes change behaviours by providing an APP with self-monitoring, self-management, doctor consultation functions.	60 months (ongoing iterative, received positive feedback)	A self-developed project at a large company	Patients, doctors, hospitals	Patients, HCPs (diabetes)	Project/product manager, (Industrial, product, visual) designer, marketers, salesmen, medical experts, policy experts,	Interaction designer and user researcher, responsible for design workflow, prototypes, design service blueprint, data analysis
P5	Design an informatic app, to provide all the information (through videos) that patients want to know and help doctors monitor their patients (with renal cancer).	18 months (completed)	A project at a small company that designs for an external hospital	Insurance providers, caregivers	Patients and HCPs (renal cancer)	Finance (CFO), graphic/UI designer, industrial/product designer, marketing manager, programmer/software engineer/developer (IT), senior partners for engineering problems and regulation checking, User researchers	Designer, make abstract concepts tangible, co-create with stakeholders, keep patients' experience in mind, balance needs of clients and patients
P6	Design a wearable sleep management system (i.e., both software and hardware) of medical grade, to provide personalised sleeping recommendations based on data monitoring.	6 months (ongoing iterative, low usage)	A self-developed project at a medium company	Collaborated with sleeping departments in hospitals, and did test with patients	Patients (sleep disorders)	Designer(s), marketer, salesmen, mechanical engineer, programmer/software engineer/developer (IT),	Product manager, project leader, and industrial designer
P7	Redesign a self-monitoring app, to improve user experience for patients with high blood pressure.	3 months (completed)	A project in an academic context that redesigns for an external company	Patients, GP, professional support from the company	Patients (high blood pressure)	Design students	Designer, design researcher
P8	Design a new diagnostic center, to help people with cancer symptoms get a quick efficient diagnosis and better patient experience.	18 months (ongoing)	A project at a large company that designs for an external hospital	Patients, hospitals, GP, new cancer Diagnose center, nurse specialist	Patients (cancer)	Designer(s), marketing manager, programmer/software Engineer/developer (IT),	eHealth advisers, do some concept or usability tests, show other People which solution is much more friendly to use, make infographics from the research with other colleagues, responsible for user research, evaluative research
P9	Design a mobile app, to monitor patients remotely and motivate them to overcome fear and prepare for a surgery, help care teams identify the prioritization of patient's surgery and to reduce costs for both patients and care teams.	9 months (completed)	A project at a medium company that designs for an external hospital	Ppeer patients, care teams, nurses, surgeons, and physical therapist, hospitals	Patients and HCPs (episodic care for orthopedic surgery)	Industrial/product designer, marketer, salesmen,	Team leader, responsible for product design and research activities
P10	Design a patient journey, aim to investigate the COVID-19 patients' journey map and experience through the analysis of youtube videos.	4 months (completed)	A self-developed project in an academic context	Patients	Patients (COVID-19)	Design students	Designer, design researcher (i.e., merge, match and optimize all resources, bridge multi-stakeholders)
P11	Design a patient journey interface, to give stroke patients the needed information at the right time in their whole journey.	A few months (completed)	A project at a small company that designs for an external company	Patients, patients' families, medical professionals	Patients, patients' families, and HCPs (stroke)	Designer(s),	Designer, design researcher, a spider in the middle of the web, handle the whole project individually,
P12	Design website and application interfaces, to help psychological	12 months (ongoing iterative)	A self-developed	Psycho-medical institution, psychological	HCPs (psychological therapy)	Designer(s), finance (CFO), medical experts, project/	Designer (the only designers in the team), involve in discussing

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Participants	Design context	Project duration and completeness.	Clients	Stakeholders	End-users	Team members	Self-identified roles
	therapists find the right therapy tools and modules for their patients, develop new application for mental health, start at the very beginning of new product development and company strategy.		project at a large company	therapist, yoga center, patients		product manager, yoga teacher	company vision, building information infrastructure, and realizing product functions, making ideas tangible
P13	Design a platform to help patient get all information about their surgey, e.g., cost, time duration, surgeons, and help them connect individual surgeon with hospitals which have the infrastructure to provide support and utlilize resources.	6 months (ongoing)	A self-developed project at a small company	Hospitals, surgeons, patients	HCPs, hospitals, and patients (surgery)	Designer(s), marketing manager, medical experts,	Co-founder, designer, provide design strategies for the future, business consideration
P14	Design a screening and monitoring device, to diagnose patients with respiratory disease and asthma problems.	4 months (completed)	A self-developed project at a small company	Marketer (represent patients and doctors' feedback)	Patients (respiratory diseases and asthma)	Industrial/product designer, mechanical engineer, programmer/software engineer/developer (IT), project/product manager,	Industrial designer, ideation research, appreance design, interaction design and package design
P15	Design a digital disease screening tool, to provide patients with comprehensive information.	5 months (ongoing)	A project at a large company that designs for an external hospital	Public clinics/ hospitals, patients, company	The elderly (chronic disease diagnose)	Designer(s), programmer/software engineer/developer (IT),	Designer, user research, understand user needs and scenarios, create and validate deisgn concepts
P16	Design an evidence-based fatigue management solution for persons with Multiple Sclerosis, to equalize the power dynamics between doctors, care givers and patients.	1 month (ongoing and almost fail)	A project at a large company that designs for an external company	healthcare professionals, patients	Patients (Multiple Sclerosis)	Medical experts, physical therapist, programmer/software engineer/developer (IT), service designers,	Designer, design researcher, human computer interaction expert in understanding user requirements, make a common ground and make everyone understand each other and try to combine the perspectives, translator
P17	Design an ehealth app, to improve the children and their parents' experience for pediatric acute admissions, empower the child in the journey and birng them to the center.	8 months (completed)	A project in an academic context that collaborates with an external hospital	A pediatric department/ hospital, patients, and patients' families, private caregivers	Patients and patients' families (pediatric admissions)	Designer(s)	The first designer in the pediatric department; researcher; concept testing;
P18	Design a patient information collection sheet, health-related self-assessment activities and healthcare service recommendations of a healthcare system, to collect patient information before the teleconsultation.	1 month (ongoing)	A self-developed project at a large company	Hospitals, users, national policy, a third party	Patients (general issues)	Interaction designer, mechanical engineer, programmer/software engineer/developer (IT), project/product manager, User researchers, visual designer	Lead designer, research, interaction design, design proposals, client contact
P19	Design the interface of a healthcare service system, to support patients do self-management after having a heart stent surgery.	24 months (completed and failed project)	A self-developed project at a large company	Healthcare providers form a third party, healthcare service company, nurses, hospital	Patients (post-surgery)	Medical experts, nurses, programmer/ software engineer/ developer (IT), project/product manager, service designers	Interaction design, interface and experience points, workflow design, organizing, mapping and visualizing problems, producing basic materials for team discussion
P20	Design an innovation roadmap, to translate ideas, visions, or ways in which people thought about the future of health	2.5 months (ongoing)	A project at a large company that designs for an external hospital	Doctors, nurses, patients, IT, GPs, ecosystem players,	Patients, HCPs, everyone work in the hospital (general issues)	Strategical designers and researchers	A strategic designer and a researcher, co-create with stakeholders, prioritize

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Participants	Design context	Project duration and completeness.	Clients	Stakeholders	End-users	Team members	Self-identified roles
	and connect knowledge to facilitate the design management.			ambulance workers			concepts, and create innovation roadmap
P21	Design an app, to allow busy physicians recognize patients stroke symptoms earlier by using eye measurement.	24 months (ongoing)	A self-developed project at a small company	Innovation projects manager, MBA students, data science company, GP, technical partners	Patients and HCPs (stroke)	Data scientists and researchers, MBA students, medical experts, project/product manager, technical partners	Co-founders, work on the project proposal, technical validation, to make sure that this app is going to be tested in different hospitals
P22	Design games (i.e., hardware and software), to improve the quality of life for people with cognitive disabilities.	144 months (ongoing iterative, launched)	A self-developed project at a medium company	Care homes (care staff, elderly, family members) and universities	Patients (dementia down syndrome, and autism)	Designer(s), executives, industrial/product designer, programmer/software engineer/developer (IT), project/product manager	Concept designers, sole driver of the project, entrepreneur, creative ways of designing with complexity,
P23	Design a care model, to transform the care experience of patients with insomnia.	12 months (completed)	A project at a medium company that collaborates with an external hospital	Patients and health care providers	Patients (insomnia)	Data scientists and researchers, service designers, User researchers	Lead of the strategy in service design and research with human center point of view; coordinator to set up research participants;
P24	Design concepts, to address patiesnts' emotional issues and lifestyle management by remotely monitoring their health and replacing non-digital visits by digital connections.	24 months (completed but never passed the conceptual phase)	A self-developed project at a large company	Patients, surgeons, breast clinics, primary care provider	Patients and HCPs (breast cancer survivorship)	Design interns, designer(s)	Designers, and lead of 2 experiments

References

Aasdahl, L., Marchand, G.H., Gismervik, S.Ø., Myhre, K., Fimland, M.S., Røe, C., 2020. The fear avoidance beliefs questionnaire (FABQ) does it really measure fear beliefs? Spine 45 (2), 134–140.

Ammenwerth, E., Schnell-Inderst, P., Hoerbst, A., 2012. The impact of electronic patient portals on patient care: a systematic review of controlled trials. J. Med. Internet Res. 14 (6), e162.

Bate, P., Robert, G., 2006. Experience-based design: from redesigning the system around the patient to co-designing services with the patient. BMJ Qual. Saf. 15 (5), 307–310.

Bauer, H.H., 1990. Barriers against interdisciplinarity: implications for studies of science, technology, and society (STS. Sci. Technol. Hum. Val. 15 (1), 105–119.

Bolton, R.N., McColl-Kennedy, J.R., Cheung, L., Gallan, A., Orsingher, C., Witell, L., et al., 2018. Customer experience challenges: bringing together digital, physical and social realms. J. Serv. Manag. 29 (5), 776–808.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3 (2), 77–101.

Cafazzo, J.A., St-Cyr, O., 2012. From discovery to design: the evolution of human factors in healthcare. Healthc. Q. 15 (sp), 24–29.

Carayon, P., Wooldridge, A., Hoonakker, P., Hundt, A.S., Kelly, M.M., 2020. Seips 3.0: human-centered design of the patient journey for patient safety. Appl. Ergon. 84, 103033.

Clarkson, J., Eckert, C., 2010. Design Process Improvement: a Review of Current Practice.

Commission, D., 2014. Restarting Britain2: design and public services. Annual Review of Policy Design 2 (1), 1–10.

Patient-centered design grounded in user and clinical realities: towards valid digital health. In: Cornet, V.P., Daley, C., Bolchini, D., Toscos, T., Mirro, M.J., Holden, R.J. (Eds.), 2019. Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care. SAGE Publications Sage CA, Los Angeles, CA.

Council, B.D., 2019. Framework for innovation: design Council's evolved double diamond [cited 2023 March 23]; Available from: https://www.designcouncil.org.uk/our-work/skills-learning/tools-frameworks/framework-for-innovation-design-councils-evolved-double-diamond/.

Cummins, N., Schuller, B.W., 2020. Five Crucial Challenges in Digital Health. Frontiers Media SA, 536203.

de Wit, M., Cooper, C., Reginster, J.-Y., 2019. Practical guidance for patient-centred health research. Lancet 393 (10176), 1095–1096.

Dinh, J.V., Traylor, A.M., Kilcullen, M.P., Perez, J.A., Schweissing, E.J., Venkatesh, A., et al., 2020. Cross-disciplinary care: a systematic review on teamwork processes in health care. Small Group Res. 51 (1), 125–166.

Dixon-Woods, M., McNicol, S., Martin, G., 2012. Ten challenges in improving quality in healthcare: lessons from the Health Foundation's programme evaluations and relevant literature. BMJ Qual. Saf. 21 (10), 876–884.

Dong, H., McGinley, C., Nickpour, F., Cifter, A.S., Group, I.D.R., 2015. Designing for designers: insights into the knowledge users of inclusive design. Appl. Ergon. 46, 284–291.

Dubberly, H., 2004. How Do You Design. A Compendium of Models.

Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W.S., et al., 2012. A strategy for human factors/ergonomics: developing the discipline and profession. Ergonomics 55 (4), 377–395.

The reality of design process planning. In: Eckert, C.M., Clarkson, P.J. (Eds.), 2003. DS 31: Proceedings of ICED 03, the 14th. International Conference on Engineering Design, Stockholm.

What designers think we need to know about their processes: early results from a comparative study. In: Eckert, C., Blackwell, A., Bucciarelli, L., Clarkson, P., Earl, C., Knight, T., et al. (Eds.), 2004. DS 32: Proceedings of DESIGN 2004, the 8th International Design Conference. Dubrovnik, Croatia.

Erwin, K., Krishnan, J.A., 2016a. Using design methods to provide the care that people want and need. Journal of Comparative Effectiveness Research 5 (1), 13–15.

Erwin, K., Krishnan, J.A., 2016b. Redesigning Healthcare to Fit with People. British Medical Journal Publishing Group.

Etikan, I., Musa, S.A., Alkassim, R.S., 2016. Comparison of convenience sampling and purposive sampling. Am. J. Theor. Appl. Stat. 5 (1), 1–4.

Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., et al., 2013. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. PLoS Med. 10 (1), e1001362.

Fusch, P.I., Ness, L.R., 2015. Are we there yet? Data saturation in qualitative research. Qual. Rep. 20 (9), 1408.

Gopal, G., Suter-Crazzolara, C., Toldo, L., Eberhardt, W., 2019. Digital transformation in healthcare–architectures of present and future information technologies. Clin. Chem. Lab. Med. 57 (3), 328–335.

Groeneveld, B., Dekkers, T., Boon, B., D'Olivo, P., 2018. Challenges for design researchers in healthcare. Design for Health 2 (2), 305–326.

Hasso Plattner Institute of Design at Stanford, 2010. An Introduction to Design Thinking PROCESS GUIDE.

Healthcare Design Group CEDC, 2020. Improving Improvement: A Toolkit for Engineering Better Care. Available from: https://www.iitoolkit.com/.

Hose, B.-Z., Carayon, P., Hoonakker, P.L., Brazelton, I.I.I.T.B., Dean, S.M., Eithun, B.L., et al., 2023. Work system barriers and facilitators of a team health information technology. Appl. Ergon. 113, 104105.

IDEO.org, 2015. The Field Guide to Human-Centered Design, 978-0-9914063-1-9.

Irizarry, T., Dabbs, A.D., Curran, C.R., 2015. Patient portals and patient engagement: a state of the science review. J. Med. Internet Res. 17 (6), e148.
The standard of user-centered design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. In: Jokela, T., Iivari, N., Matero, J., Karukka, M. (Eds.), 2003. Proceedings of the Latin American Conference on Human-Computer Interaction.
Jones, P., 2013. Design for Care: Innovating Healthcare Experience. Rosenfeld Media, 1933820136.
Kessler, M.M., Breuch, L.-A.K., Stambler, D.M., Campeau, K.L., Riggins, O.J., Feedema, E., et al., 2021. User Experience in health & medicine: building methods for patient experience design in multidisciplinary collaborations. J. Tech. Writ. Commun. 51 (4), 380–406.
Kleinsmann, M., Valkenburg, R., Sluijs, J., 2015. A Designerly Approach to Managing Collaborative Practices in Networked Innovation. Results of the IOP-IPCR project.
Lupton, D., 2017. Digital health now and in the future: findings from a participatory design stakeholder workshop. Digital health 3, 2055207617740018.
Martin, J.L., Craven, M.P., Norris, B.J., 2005. MATCH: a new industry-focused approach to medical device development. Effect of Operational Variables on Nitrogen Transformations in Duckweed Stabilization Ponds, p. 298.
Martin, J.L., Clark, D.J., Morgan, S.P., Crowe, J.A., Murphy, E., 2012. A user-centred approach to requirements elicitation in medical device development: a case study from an industry perspective. Appl. Ergon. 43 (1), 184–190.
McInnes, E., Haines, M., Dominello, A., Kalucy, D., Jammali-Blasi, A., Middleton, S., et al., 2015. What are the reasons for clinical network success? A qualitative study. BMC Health Serv. Res. 15 (1), 1–9.
Melles, M., Albayrak, A., Goossens, R., 2021. Innovating health care: key characteristics of human-centered design. Int. J. Qual. Health Care 33 (Suppl. ment_1), 37–44.
Mummah, S.A., Robinson, T.N., King, A.C., Gardner, C.D., Sutton, S., 2016. IDEAS (Integrate, Design, Assess, and Share): a framework and toolkit of strategies for the development of more effective digital interventions to change health behavior. J. Med. Internet Res. 18 (12), e317.
Pagliari, C., 2007. Design and evaluation in eHealth: challenges and implications for an interdisciplinary field. J. Med. Internet Res. 9 (2), e614.
Patrick, K., Hekler, E.B., Estrin, D., Mohr, D.C., Riper, H., Crane, D., et al., 2016. The Pace of Technologic Change: Implications for Digital Health Behavior Intervention Research. Elsevier, pp. 816–824.
Paulovich, B., 2015. Design to Improve the Health Education Experience: using participatory design methods in hospitals with clinicians and patients. Visible Lang. 49 (1–2).
Perry, S.J., Catchpole, K., Rivera, A.J., Parker, S.H., Gosbee, J., 2021. 'Strangers in a strange land': understanding professional challenges for human factors/ergonomics and healthcare. Appl. Ergon. 94, 103040.
Persson, J., 2017. A review of the design and development processes of simulation for training in healthcare–A technology-centered versus a human-centered perspective. Appl. Ergon. 58, 314–326.
Persson, J., Rydenfält, C., 2021. Why are digital health care systems still poorly designed, and Why is health care practice not asking for more? Three paths toward a sustainable digital work environment. J. Med. Internet Res. 23 (6), e26694.
Porter, M.E., 2010. What is value in health care. N. Engl. J. Med. 363 (26), 2477–2481.
Shadlyn, T., Hubbard, L., Maly, T., Dalgish, H., 2022. A Marriage in Practice: the Role of Design Research in the World of Medical Science.
Streeton, R., Cooke, M., Campbell, J., 2004. Researching the researchers: using a snowballing technique. Nurse Res. 12 (1), 35–47.
The Beryl Institute, 2021. Defining Patient Experience. The Beryl Institute Website [cited 2021 December 6]; Available from: https://www.theberylinstitute.org/page/DefiningPX.
Tsekleves, E., Cooper, R., 2017. Emerging trends and the way forward in design in healthcare: an expert's perspective. Des. J. 20 (Suppl. 1), S2258–S2272.
Wang, T., Giunti, G., Melles, M., Goossens, R., Wang, T., Giunti, G., et al., 2022a. Design-relevant factors affecting the patient experience in digital health: preliminary results of an umbrella systematic review. Stud Health Technol Inform 862–866.
Wang, T., Giunti, G., Melles, M., Goossens, R., 2022b. Digital patient experience: umbrella systematic review. J. Med. Internet Res. 24 (8), e37952.
Building understanding of experience design in digital health: preliminary results based on semi-structured interviews. In: Wang, T., Qian, S., Zhu, H., Goossens, R., Giunti, G., Melles, M. (Eds.), 2022c. International Conference on Healthcare Systems Ergonomics and Patient Safety. Springer.
Wang, T., Giunti, G., Goossens, R., Melles, M., 2024. Timing, indicators, and approaches to digital patient experience evaluation: umbrella systematic review. J. Med. Internet Res. 26 (1), e46308.
World Health Organization, 2007. Everybody's Business–Strengthening Health Systems to Improve Health Outcomes: WHO's Framework for Action, 9241596074.
World Health Organization, 2018. Classification of Digital Health Interventions V1. 0: a Shared Language to Describe the Uses of Digital Technology for Health. World Health Organization.
World Health Organization, 2020. Digital Implementation Investment Guide (DIIG): Integrating Digital Interventions into Health Programmes, 9240010564.