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Design research in healthcare: a systematic literature review of key design journals

Healthcare is a major industry, but we know little about the involvement of design researchers in this field. We report the results of a focused mapping review and synthesis (FMRS) of healthcare design research. We systematically reviewed six leading design journals to map the contributions to date of the design research community in healthcare. A search of the Web of Science yielded 75 articles, of which 44 were ultimately selected for analysis. We extracted data on article characteristics, design research topics and healthcare-related themes to map the current state of design research applied to healthcare. We discuss the main patterns that emerge from this review, including a focus on products and hospital settings, a disregard for prevention, a strong commitment to stakeholder engagement, or a focus on the early stages of design. We lay out perspectives for future research and discuss the biases potentially incurred by the FMRS methodology.

Keywords: design research, healthcare, systematic literature review, focused mapping review and synthesis

Wordcount: 6045 words excluding title, abstract, figures and references

1 Introduction

Even if healthcare accounts for 10% of GDP in developed products (OECD 2021), poor design remains surprisingly pervasive in this area. Patients can hurt themselves with poorly designed products (Brown et al. 2016), professionals can be fooled by unintuitive design (Reeson, Kyeremanteng, and D'Egidio 2018), and improvement efforts can drag unnecessarily on for lack of simple design thinking practices (Kriznik, Lamé, and Dixon-Woods 2019). The potential for designers to improve healthcare seems clear (Wears and Fairbanks 2016; Gray 2016; Mathews and Pronovost 2011), but how does design research contribute to this?

Researchers have published reviews on the use of specific design approaches, like design thinking (Altman, Huang, and Breland 2018; Oliveira, Zancul, and Fleury 2021; McLaughlin et al. 2019), or in specific areas of healthcare, such as patient safety (Clarkson et al. 2004) or the management of cognitive decline and dementia (Patou et al. 2020). Yet, we were unable to find a synthesis of healthcare design research that would encompass the diversity of design research (McMahon 2012).

In this article, we aimed to map design researchers' published contributions in healthcare. Rather than retrieving and analysing everything that has been published in relation to the application of design principles in healthcare contexts, our aim was to understand what is happening within the design research community. Our driving question was "How does the design research community investigate healthcare issues?" This can be broken down in sub-question such as:

- What design concepts and approaches do we apply when studying healthcare?
- Who, in the design research community, works on healthcare?
- What aspects of this human enterprise do we focus on? Which aspects have we left out of our investigations?

Although there is no definitive definition of who constitutes the design research community, we used the Design Society's definition statement to drive our work: "an association of individuals across the world who deeply care about design: How we create new artefacts and systems, how we think about this creation process, and what is the impact of human-created artefacts on the world we live in and on ourselves."¹ With this definition, the design research community gathers individuals from diverse disciplinary

¹ <https://www.designsociety.org/1/About+the+Design+Society>, consulted on 14 April 2022.

backgrounds, ranging from engineers to management scholars, ergonomists, industrial designers or psychologists (McMahon 2012; Papalambros et al. 2015; Christensen and Ball 2019).

2 Material and methods

Given our objectives and our ambition to map a defined field of knowledge rather than to aggregate a body of evidence, we followed the focused mapping review and synthesis (FMRS) approach proposed by Bradbury-Jones et al. (2019). FMRS is systematic in that it is "undertaken according to a fixed plan or system or method" (Gough and Thomas 2017, 5). Researchers conducting a FMRS focus on a selected set of key journals in a field, which they search systematically. The synthesis they produce focuses on the topics, designs and methodologies of included articles, rather than on their results.

2.1 Search

We sought articles discussing the application or study of design in healthcare. Healthcare was defined as the set of services provided by a country or an organization to treat the physically and the mentally ill. We did not restrict ourselves to specific study types or to a given timeframe.

FMRS involves reviewing a defined set of journals on a topic. The journals are selected "according to their likelihood to contain the required information" (Bradbury-Jones et al. 2019). In our case, the journals had to reflect the diversity of the design research community. We used the results of previous research on design scholars' perception of the quality of design journals (Gemser et al. 2012), and focused on general design journals. This led us to include the *Journal of Engineering Design*, *Design Studies*, the *International Journal of Design*, and *Design Issues*. Following the arguments put forward by Cash (2018), we also included *Research in Engineering Design* to represent

the engineering design tradition (only covered in the *JED* in the previous four journals), and the *Design Science Journal* as an emerging interdisciplinary journal.

This list implicitly defines the vision of design taken in this review: “the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes” (Buchanan 2001); a multifaceted endeavour, studied by a multidisciplinary research community (McMahon 2012; Cash 2018). We acknowledge that design projects can sometimes be published in other fields, e.g., clinical medicine or public health. However, design-oriented papers published in health venues are often less detailed about the nature of the design processes undertaken and more focused on clinical and medico-economic outcomes. Their target readership is also different, centred on healthcare specialists or a multidisciplinary audience with very limited knowledge of design. In this review, we want to focus on the design research dimension and to explore what design researchers discuss inside their community, in line with the FMRS method. Our list of journals balances different traditions of design research, and includes the official outlets of important learnt societies (*JED* is endorsed by the Design Society, *DSJ* is its official journal, *DS* is the Design Research Society’s journal).

We searched these six journals on the Web of Science (webofknowledge.com) on October 12, 2020, with the following search string: “TOPIC: health OR healthcare OR medic* OR pharma* OR nurs* OR hospital OR doctor OR physician OR patient) AND PUBLICATION NAME: ("journal of engineering design" or "research in engineering design" or "international journal of design" or "design studies" or "design issues" or "design science")”.

Two of the authors (SHD and GL) screened articles in two stages. First, both reviewers filtered articles based on title and abstract. When disagreements occurred, the

two reviewers solved them through discussion until reaching a mutual agreement on the inclusion of articles. The same reviewers then proceeded in the same way with full text. The only criterion for excluding an article was if it did not report on design research in a healthcare context.

2.2 Data extraction and analysis

Once we had obtained our set of included articles, one of us (SHD) coded data extracted from the articles. After that, a second reviewer (GL) analysed the codes and documented instances where he disagreed with the initial coding. A third reviewer (MJ) made the final decision in these cases.

For each included article, we extracted the publication date. We also coded the type of article, using four categories:

- Conceptual articles that propose new theoretical frameworks eliciting relationships between concepts (Gilson and Goldberg 2015; Callahan 2010).
- Opinion articles that put forward their authors' personal experience and convictions on a contested topic.
- Literature reviews that present a state of the art of academic knowledge on a given topic.
- Empirical articles that report on the collection and analysis of primary or secondary data.

2.2.1 Authors' countries and disciplines of affiliation

For each article, we listed the countries of affiliation of the co-authors. These codes were combined at the article level so that if an article had two authors affiliated to Dutch

institutions and one affiliated to a Belgian institution, this article counted for one for the Netherlands and one for Belgium.

In addition, we extracted the disciplinary affiliations of authors, following the method used by Christensen and Ball (2019). We used the same seven disciplinary categories, plus a "medical and health sciences" category, which was missing in Christensen and Ball's analysis but was central to our own project (details in appendix 2). For each article, we coded the disciplinary affiliation of all co-authors, using affiliations at the department level. Following the same principle as for countries, for each article, we listed the unique disciplines involved, without double counting. For example, if an article had two authors with affiliation in Technology and Engineering, and one co-author with an affiliation in Natural sciences, this article counted for one for Technology and engineering and one for Natural sciences. When co-authors had multiple affiliations, we counted them all. We occasionally sought additional online information to categorise affiliations when department names were unclear (e.g. those using acronyms), and coded "not classifiable" in last resort.

2.2.2 *Design research characteristics*

The *design research* dimension documents research approaches those authors adopted, the design methodology they applied, and the life cycle stage they studied (complete details in appendix 2). First, we coded the design research categories to which articles belonged, based on Horvath's framework of knowledge categories in engineering design research (Horváth 2004). The reviewers assigned as many categories as they felt appropriate to each article.

Second, we coded the "framing methodology" based on Horvath's comparison of three broad methodological approaches in design research (Horváth 2007, 2008) :

- Research in design context, which concentrates on building and proving theories about how design proceeds,
- Design inclusive research, which supports constructive operative design research by the involvement of design in the research process,
- Practice-based design research uses operative research methods and is deeply linked to industrial design engineering, architecture, and media design.

To assess the level of implementation of the findings in each article, we adapted a categorization used by Jahangirian et al. (2012) in operational research, which describes the extent to which an article tackles a defined practical problem:

- Real problem-solving articles, for articles reporting projects with a high level of implementation and user engagement, where the authors genuinely get immersed in analysing a situation, improving it, and testing their ideas through pilots or full-scale implementations.
- Hypothetical problem-solving articles, for articles based on a case study to solve a real-life problem but with a low engagement level from users. The authors have observed a situation and have deduced solution proposals but without testing them in reality (e.g., proposition of a framework based on interviews without empirical evaluation).
- Methodological articles, for articles with no case study and a low level of user engagement to design or evaluate a problem-solving strategy.
- No problem-solving intention, for articles where problem-solving is not the authors' objective (e.g., descriptive research of design practices with no propositions for improving practice)

Finally, we used Pahl and Beitz's seminal model of the product design process (1996) to describe the life cycle stage at which the researchers operate in their article. We completed the original stages (clarification of task, conceptual design, embodiment design, detail design) with later stages, manufacture, usage, and end of life. Articles could cover several lifecycle stages.

2.2.3 *Healthcare-related topics of interest*

We extracted the following information on the healthcare-related characteristics of the articles (complete details available in appendix 2):

- (1) The type of artifact studied as part of the design research: product/device, service or product-service system, organisations and processes, and architecture and built environment (including interior design and space layout).
- (2) The healthcare services to which the research applies: primary care (e.g., general physicians, community nurses), home and community care (home monitoring and nursing homes), hospital care (secondary, tertiary, and quaternary care), healthcare system, medical device industry, or not classifiable.
- (3) The medical specialty: medicine (including primary care and intensive care), surgery/anaesthesiology, mental health, laboratory work, or not classifiable.
- (4) The type of health condition studied: chronic, acute, both, prevention, and not classifiable.
- (5) Stakeholder engagement in the design process, with the following typology of stakeholders: Designers (including engineers and architects), Patients (including pre-users) and relatives, Health care professionals, Managers, Industry (excluding

designers), and None (where there was no evidence of stakeholder engagement).

2.3 Analysis

In the analysis stage, we strayed from the main FMRS method, in which synthesis is "typically" narrative (Bradbury-Jones et al. 2019). We summarised our findings quantitatively (which FMRS proponents also accept), counting the occurrence of each code in absolute value and as a percentage of included articles. We presented our results in tabular and graphical format, using bar charts when categories were not mutually exclusive (e.g., for life cycle stage, because articles can cover several stages) or pie charts for mutually exclusive categories (e.g., research framing methodology).

3 Results

We identified 75 articles through our search, of which we included 44 for data extraction and analysis (the full list of references is available in Appendix 1). Figure 1 shows the PRISMA 2020 Flow Diagram for the review (Page et al. 2021). Articles identified in the database search were excluded if they did not report on design research in a healthcare context (e.g., (Snider et al. 2017), which was possibly detected because it has "engineering project health monitoring" as a keyword, or (Cash et al. 2015), possibly detected because of the Keyword Plus feature of the Web of Science that adds metadata based on the references cited in an article).

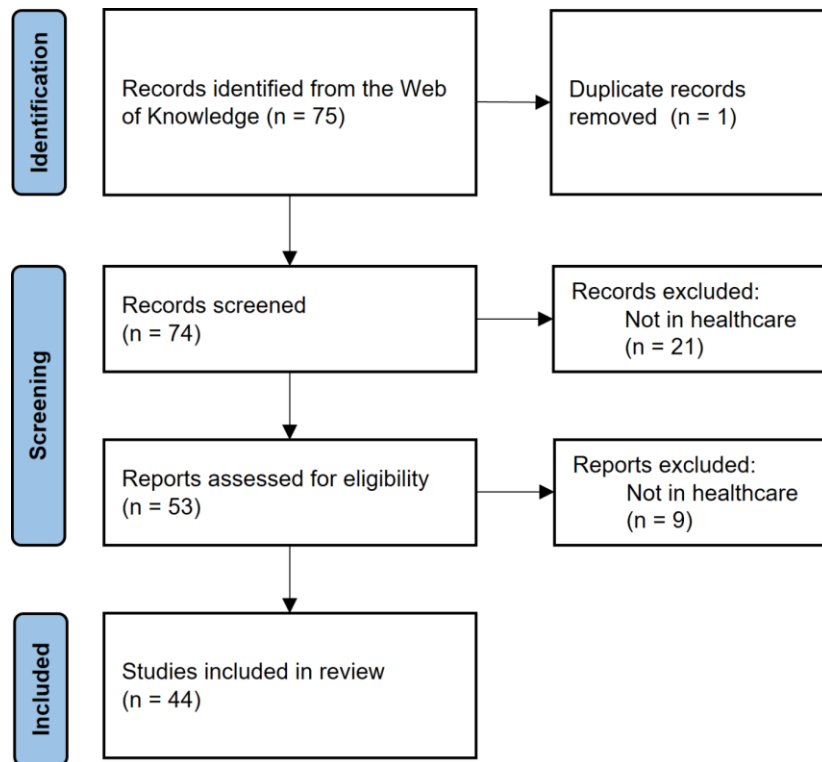


Figure 1. PRISMA 2020 flow diagram.

All included articles were published after 2002, with 29 (66%) published after 2013 (inclusive) (Figure 2). Included articles accounted for 1.47% of the 2984 articles published between 2000 and 2020 in the six design journals selected for this review. Most articles were empirical (38, 86.4%). We also included one literature review (2.3%), two opinion articles (4.5%) and three conceptual articles (6.8%).

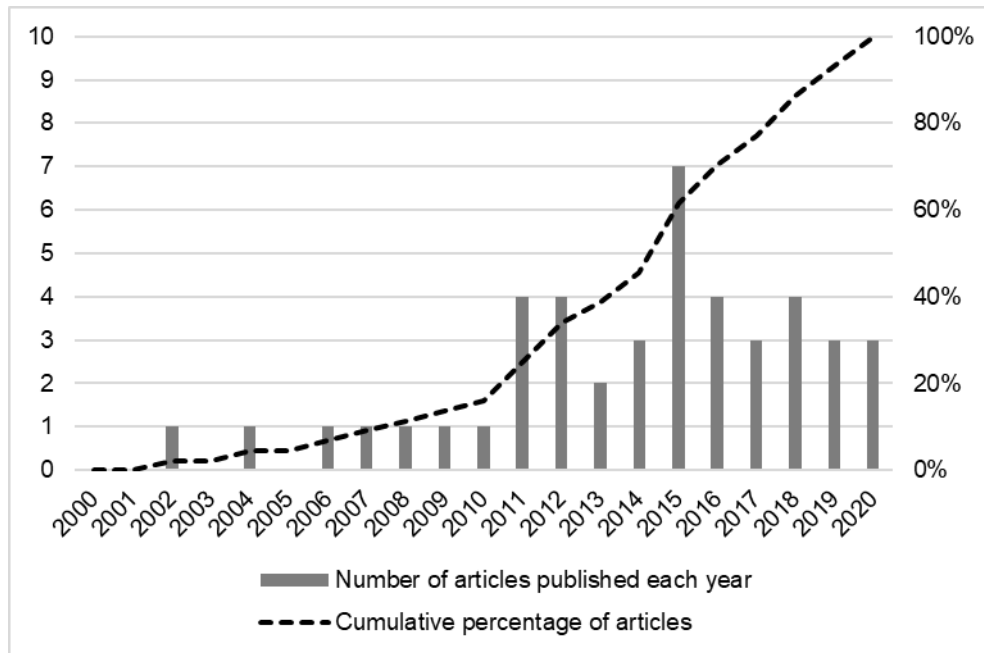


Figure 2. Number of articles included in our review, per year of publication.

3.1 Authors' countries and disciplines of affiliation

Three countries were represented in more than 10% of articles: Denmark (12 articles), the US (10 articles), the United Kingdom (UK) (10 articles), and the Netherlands (5 articles) (Figure 3). The contribution of these countries did not vary over time (Denmark: 6 articles before 2014 and 6 since 2015, US: 5 and 5, UK: 5 and 5, Netherlands: 2 and 3).

“Applied Arts, Design and Architecture” (20 articles) and “Technology and Engineering” (19 articles) were the two disciplinary domains most represented. This predominance did not vary much over time (Applied Arts was present in eight of the 20 articles published pre-2014 and twelve of the 24 articles published post-2015, for Technology and Engineering the figures are 7 and 12, respectively). Co-authors with medical affiliations were present in four articles pre-2014 and only one post-2015.

Twelve articles (27.3%) had co-authors from two or more disciplinary domains (four of 20 articles published pre-2014, eight of 24 post-2015).

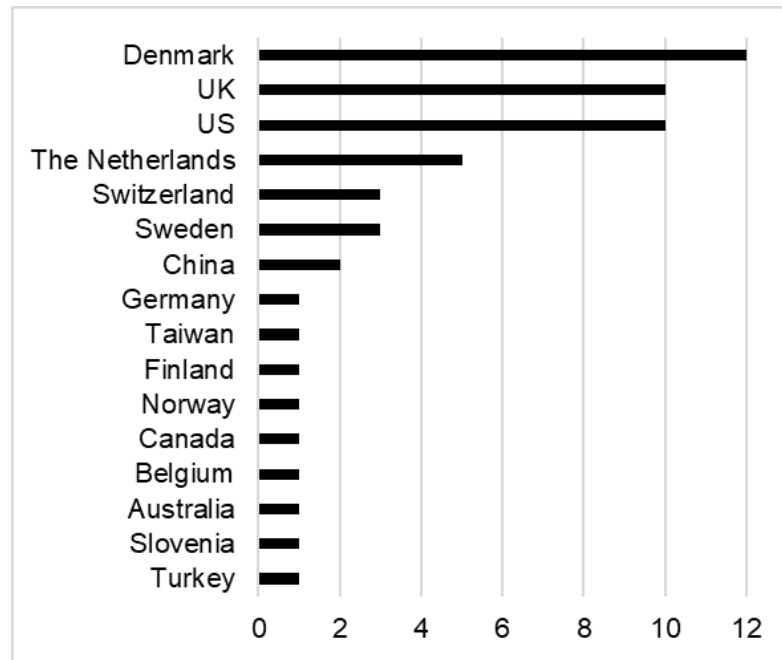


Figure 3. Number of articles with at least one author affiliated to a local institution, per country.

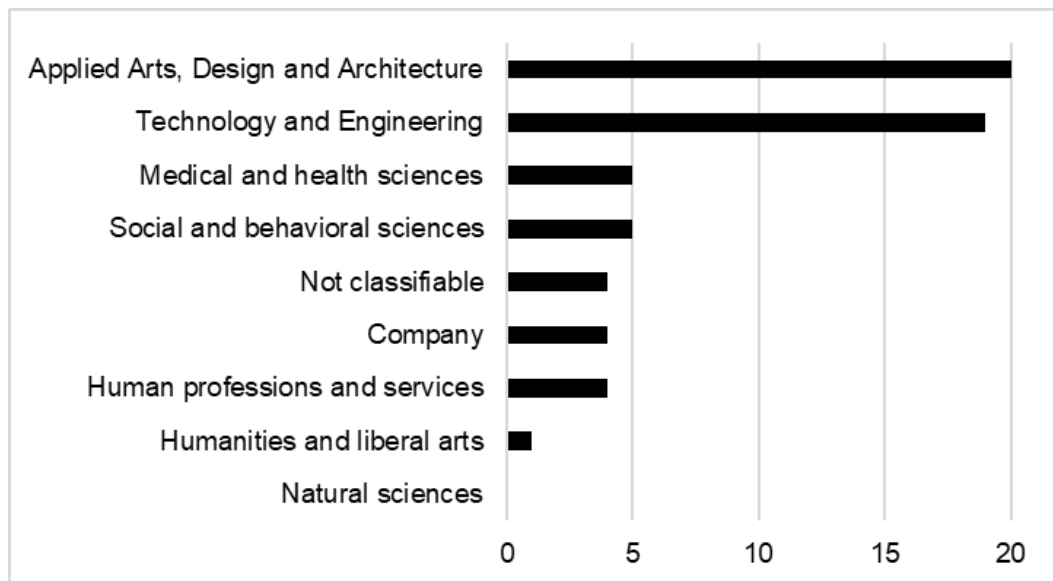


Figure 4. Number of articles with at least one author with an affiliation in a disciplinary domain, per disciplinary domain.

3.2 Design research characteristics

3.2.1 Design categories

All nine categories of design research defined by Horváth (2004) were represented in the included articles, albeit with contrasted frequencies (Table 1). The most frequent categories that were mostly represented were Human assets (29 articles, 65.9%) and Design methodology (26 articles, 59.1%). "Human assets" includes design ergonomics and design cognition. An example is Markussen's study of emotional response to products and how it affects the way users perceive the way they suppose they are expected to use a product (2009). "Design methodology" includes methodologies of design and design modelling. In a study of the refurbishment of a hospital ward, Eckert et al. (2012) investigate the strategies designers use to adapt to severely constrained design spaces.

These three categories remained relatively stable across the pre-2014 and post-2015 periods. The number of articles addressing "Processes knowledge" decreased strongly after 2015 (eleven articles before 2014, only two after 2015).

3.2.2 Framing methodology

The split between research framing methodologies slightly favoured Practice-based design research (18 articles, 40.98%) over Research in design context (15, 34.1%) and Design inclusive research (11, 25%) (Table 1). An example of Design inclusive research is the article by Clarkson (2018), where the author reports on the recent work of engineers, clinicians, and healthcare leaders, who went on to collaboratively explore how an engineering systems approach could be applied to improve healthcare, defining a specific framework for health services. Onarheim (2012) illustrates Research in design context. The author studies an international disposable medical equipment company, where he investigates how engineers design manage to design creatively within imposed

constraints. Finally, Practice-centred design is common in industrial design research (Horváth 2007). For example, Kelly and Matthews (2014) present a design case from the medical device industry where they questioned the central place of the concepts of “use” and “users” in design.

Table 1. Repartition of included articles in design-related categories.

Category	Code	Number of articles (% of 44 included articles)	Number of articles pre-2014 (% of 20 articles)	Number of articles post-2015 (% of 24 articles)
Design categories	Human assets	29 (65.9)	14 (70.0)	15 (62.5)
	Design methodology	26 (59.1)	10 (50.0)	16 (66.7)
	Design application	16 (36.4)	9 (45.0)	7 (29.2)
	Artifact knowledge	13 (29.5)	5 (25.0)	8 (33.3)
	Processes knowledge	13 (29.5)	11 (55.0)	2 (8.3)
	Design Knowledge	7 (15.9)	3 (15.0)	4 (16.7)
	Design theory	6 (13.6)	1 (5.0)	5 (20.8)
	Design philosophy	2 (4.5)	0 (0.0)	2 (8.3)
	Design technology	2 (4.5)	1 (5.0)	1 (4.2)
Framing of methodology	Research in design context	15 (34.1)	6 (30.0)	9 (37.5)
	Design inclusive research	11 (25)	5 (25.0)	6 (25)
	Practice-based design research	18 (40.9)	9 (45.0)	9 (37.5)
Level of implementation	Real problem solving	17 (38.6)	8 (40.0)	9 (37.5)
	Hypothetical problem solving	15 (34.1)	8 (40.0)	6 (25.0)
	Methodological article	5 (11.4)	4 (20.0)	1 (4.2)
	No problem-solving	7 (15.9)	3 (15.0)	3 (12.5)
Life cycle stage	Clarification of task	32 (72.7)	15 (75.0)	17 (70.8)
	Conceptual design	22 (50)	11 (55.0)	11 (45.8)
	Embodiment design	22 (50)	13 (65.0)	9 (37.5)

	Detail design	12 (27.3)	7 (35.0)	5 (20.8)
	Manufacture	3 (6.8)	2 (10.0)	1 (4.2)
	Usage	7 (15.9)	2 (10.0)	5 (20.8)
	End of life	0 (0)	0 (0.0)	0 (0.0)
	NA	1 (2.3)	0 (0.0)	1 (4.2)

3.2.3 *Level of implementation*

Most articles included Real Problem Solving (17/44, i.e., 38.6%) or Hypothetical problem solving (15/44, i.e., 34.1%), with Methodological articles (5, 11.4%) and articles with No problem-solving (7, 15.9%) representing only a fraction of our sample. Clarkson et al. (2004) is a good example of Hypothetical problem solving. After a literature review, interviews, workshops and case reviews, the authors propose a set of recommendations for improving patient safety through design in the UK. The recommendations are based on research, but the article does not report on their implementation. In Real problem solving, a framework, tool or hypothesis is applied to real-life problems and data. As an illustration, Petersen and Riisberg (2016) explore the complex interplay between the different actors when designing a new uniform for healthcare professionals in a Danish region. Some articles contained no attempt at problem-solving. For example, Kasali and Nersessian (2015) report ethnographic research on the role of designers in interdisciplinary contexts as they engage with other experts. The authors aim at “providing insights on practices employed in interdisciplinary design”, but do not seek to improve these practices. Hargraves (2018) discusses the application of human-centred design in healthcare, building on published examples, but does not report original applications of this approach.

3.2.4 Life cycle stage

The articles we included mostly reported on early phases of the life cycle stage, focusing on clarification of task, conceptual design, and embodiment design (Table 1). For example, Patou et al. (2020) present a systematic review of the literature to assess how well the P4 vision for healthcare (predictive, preventive, personalized, and participative) is included in technology-based interventions for dementia. P4 provides requirements and concepts that should be included early in the design process. Another example is Høiseth and Keitsch (2015), who aimed to capture "the perspectives of the phenomenon of care in the case of children's medical treatment", which is part of the preliminary exploration of context and practices before design. The later product life cycle phases, Manufacture and Usage, were underrepresented (3 and 7 articles, respectively), while no article addressed the End-of-life stage.

3.3 Healthcare-related topics of interest

3.3.1 Type of artifact studied

Most articles focused on devices (27 articles, i.e., 61.4%). This predominance appeared stable through the two periods we studied (twelve articles out of 20 pre-2014, and 15 out of 24 post-2015). An extensive range of devices was studied, for example, infusion pumps (Alexander and Clarkson 2002), prosthetics (Vukašinović, Kolšek, and Duhovnik 2007), robotic beds (Brodersen, Hansen, and Lindegaard 2015), or medical devices that could assist in inserting contraceptive implants (Deininger et al. 2019). Eleven articles (25%) focused on the care environment, such as new concepts for patient rooms (Kasali and Nersessian 2015; Ziegler 2015; Buskermolen et al. 2015) or refurbishment of a hospital ward (Eckert et al. 2012). Nine articles (i.e., 14%) dealt mainly with socio-technical and organizational issues. For example, an article focused on participation in designing an IT

system (Østergaard, Simonsen, and Karasti 2018), while van Stralen (2008) develops a high-reliability organization within intensive care unit (ICU) and a subacute care facility. Finally, eight articles (i.e., 18.2%) looked at service and service-product systems, such as a home telehealth system (Lehoux et al. 2011) or the design of ambulatory healthcare from a service design perspective (Lee 2011).

Table 2. Repartition of included articles in healthcare-related categories.

Code		Number of articles (% of 44 included articles)	Number of articles pre-2014 (% of 20 articles)	Number of articles post-2015 (% of 24 articles)
Type of artefact studied	Devices	27 (61.4)	12 (60.0)	15 (62.5)
	Architecture and built environment	11 (25)	4 (20.0)	7 (12.5)
	Organizations and processes	9 (20.5)	3 (15.0)	6 (25.0)
	Services or product-service systems	8 (18.2)	5 (25.0)	3 (29.2)
Healthcare services studied	Hospital care	18 (40.9)	7 (35.0)	11 (45.8)
	Home and community care	13 (29.5)	7 (35.0)	6 (25.0)
	Medical device industry	6 (13.6)	2 (10.0)	4 (16.7)
	Primary care	5 (11.4)	2 (10.0)	3 (12.5)
	Healthcare system	1 (2.3)	1 (5.0)	0 (0.0)
	Not classifiable	3 (6.8)	2 (10.0)	1 (4.2)
Medical specialty	Medicine (including primary care and intensive care)	24 (54.5)	12 (60.0)	12 (50.0)
	Surgery and anaesthesiology	6 (13.6)	3 (15.0)	3 (12.5)
	Mental Health	3 (6.8)	0 (0.0)	3 (12.5)
	Laboratory test	1 (2.3)	1 (5.0)	0 (0.0)
	Not classifiable	13 (29.5)	5 (25.0)	8 (33.3)
Type of health condition	Chronic	19 (43.2)	10 (50.0)	9 (37.5)
	Acute	12 (27.3)	6 (30.0)	6 (25.0)
	Both chronic and acute	4 (9.1)	4 (20.0)	0 (0.0)
	Prevention (contraception)	1 (2.3)	0 (0.0)	1 (4.2)
	Not classifiable	16 (36.4)	8 (40.0)	8 (33.3)
Stakeholders involved	Designers (including engineers and architects)	25 (56.8)	11 (55.0)	14 (58.3)
	Health care professionals	21 (47.7)	10 (50.0)	11 (45.8)

	Patients (including pre-users) and relatives	20 (45.5)	9 (45.0)	11 (45.8)
	Managers	8 (18.2)	5 (25.0)	3 (12.5)
	Industry (excluding designers)	2 (4.5)	1 (5.0)	1 (4.2)
	None	6 (13.6)	3 (15.0)	3 (12.5)

3.3.2 *Healthcare services*

We could identify a healthcare service related to the design research for 41 out of 44 articles (Table 2). Hospital care was the main focus of attention, followed by home and community care. The medical device industry and primary care received less attention, and only one article took a systemwide perspective.

3.3.3 *Medical specialty*

We could link the research object to a particular medical specialty for 31 articles out of the 44 articles included. Most articles focused on medicine and surgery/anaesthesiology, with three articles investigating mental health and one looking at medical laboratories (Table 2).

3.3.4 *Type of health condition*

We were able to identify at least one type of pathology investigated in 28 out of the 44 included articles (Table 2). Chronic diseases received more attention than acute diseases, being present in 19 articles against twelve, with four additional articles studying both types of diseases. Chronic diseases included dementia, diabetes and hearing impairment (Tobiasson et al. 2015; Patou et al. 2020; Kelly and Wensveen 2014). An example of a study of acute disease is van Stralen's account of changing care culture in a paediatric

intensive care unit (van Stralen 2008). One article explored prevention issues (contraception, in Deininger et al. 2019).

3.3.5 Stakeholder engagement

Six studies did not include any stakeholder engagement (Table 2). In other articles, researchers most often engaged with designers (25 articles), patients and relatives (20 articles), and healthcare professionals (21 articles). For instance, Tobiasson et al. (2015) carried out an experimental field study intending to assess participatory design's usefulness in implementing exergames in dementia care units. Patients and caregivers were strongly involved in the study. In another study, Lin et al. (2011) involved various stakeholders (e.g., staff nurses, unit assistants, managers, educators, discharge planners, physicians, ancillary support department, and designers) in the design process of a new model for nursing communication and knowledge handover at Kaiser Permanente. Similarly, Clarkson (2018) held workshops with multiple groups of stakeholders across the healthcare industry (primary/secondary healthcare professionals, supply chain stakeholders, and patient support groups) to co-design a systems approach to improve healthcare.

4 Discussion

4.1 Implications for the development of healthcare design research

4.1.1 Beyond products and hospitals and into services and prevention

Our review pictures healthcare design research as heavily hospital- and product-focused. Researchers spent most of their effort on products, at the expense of services and product-service systems (Xing, Rapaccini, and Visintin 2017). Much progress probably remains to be done on the ergonomics, usefulness, and safety of healthcare products. However,

digital services in healthcare are a booming field (Doraiswamy et al. 2020), and design researchers need to keep pace with these evolutions if we want to stay relevant. It would be interesting to investigate whether this bias towards products is true for the whole field of design, as services are an increasingly dominant form of economic activity in advanced economies (Schettkat and Yocarini 2006).

Whatever the type of artefact, most articles focused on the upstream phases of the lifecycle (clarification of task, conceptual design, and embodiment design). It may be because healthcare design research is still in its early development, and we still need to feed our "knowledge base" of healthcare (Clarkson et al. 2004). However, later phases also deserve attention, such as detailed design, manufacturing, usage, and, importantly end-of-life. Healthcare cannot ignore the climate crisis, and much remains to be done to improve sustainability and circularity in the sector (Guzzo et al. 2020). However, we did not look in sustainability research journals, where some of this research may be published.

The rapid development of new digital technologies affects patient work as part of their care (Ancker et al. 2015), but home and community care remain much less studied than hospitals, which accounted for almost half of the articles in our sample. Primary care and its many challenges (Frenk 2009) also deserve better attention, but design researchers have only delved into this area.

Finally, chronic diseases have received more attention than acute diseases in our sample. This reflects the current healthcare situation in developed countries, where diabetes, dementia or hypertension are major concerns and where the care for once acute diseases like cancer sometimes take characteristics of chronic care with progresses in treatment. Despite this good balance between acute and chronic diseases, the apparent lack of research on prevention is concerning (Bauer et al. 2014). As we focused on healthcare, it is we missed these articles in our search; the area of design-enabled

prevention would require specific attention in future research and evidence synthesis. Beside prevention, the limited presence of mental health in our sample (only three articles) is concerning given the global burden of mental illness (Vigo, Thornicroft, and Atun 2016).

4.1.2 *Deepening understanding of stakeholder engagement*

Most articles reported good levels of implementation and encouraging levels of stakeholder engagement. Design researchers appear more inclined to tackle the practical issues of healthcare than to engage in conceptual discussions, a trend further evidenced by the focus on the design categories "Human assets", "Design methodology" and "Design application".

We could expect these findings in an applied sub-field, but it is still comforting to see that researchers engaged in equal proportions with patients and healthcare professionals. Patients and professionals essentially co-produce healthcare services (Batalden et al. 2016), and it seems important to see engagement with both. In this, design research is ahead of much health research that still struggles with "patient and public involvement and engagement" (Ocloo and Matthews 2016; Blackburn et al. 2018). Stakeholder engagement may have been even higher, had we included *CoDesign* in our set of journals.

Nonetheless, we did not analyse the details of stakeholder engagement, which leaves some questions unanswered. Were patients and professionals co-designers, or simply interviewed to understand how they used products? We need better knowledge of how healthcare design researchers engage with stakeholders, to understand how power and knowledge imbalances are taken into account and explore the rationale and political stance behind this engagement (Williams et al. 2020). This will require empirical

research, as few design research publications report interactions in enough detail to explore these issues.

4.1.3 Expanding national and disciplinary diversity

Healthcare design research is geographically concentrated in a small number of countries, with Denmark, the UK, the US, and the Netherlands playing the leading roles. We can only speculate on the reasons for the limited contribution or absence of other countries. Funding for healthcare design research may be more easily available in some countries, and local dynamics also explain the contrasted development of research areas between countries. We can only hope that more countries will join in developing a strong healthcare design research stream.

Researchers from health and medical sciences co-authored only five of our 44 articles (11,4%); yet, authors reported engaging with healthcare professionals in almost half (47.7%) of the articles. Design researchers and healthcare professionals work together, but they do little research together: healthcare professionals appear as clients or stakeholders, possibly co-designers, but not co-researchers. This might be because none of the six journals we analysed is included in PubMed, the leading database for health sciences, and the results of joint projects may be published separately in design and health sciences journals. Indeed, researchers in the health and medical sciences are under significant professional and promotional pressure to publish in medical journals, often making these venues the primary or only venue chosen for reporting their projects.

Interdisciplinarity is not an end in itself, but interdisciplinary collaborations hold great prospects in healthcare (Smye and Frangi 2021). Even aside from collaborations with health researchers, less than a third of the articles (12 articles, 27.3%) had co-authors from two or more disciplinary domains. Current efforts to promote such collaborations are reassuring (Komashie et al. 2019).

4.2 *Strengths and limitations of the study*

In conducting this systematic review of the design research literature in healthcare, we applied a published methodology (Bradbury-Jones et al. 2019), which ensures the reproducibility of our process. Following best practices, we double-screened articles. Although we did not perform double-blind data extraction, all records were verified by a second reviewer, and discussed with a third when required. Despite these precautions, we note three main limitations in our study.

First, following the FMRS method (Bradbury-Jones et al. 2019), we worked with a subset of selected journals. We have reused a list proposed by Cash (2018) for his methodological literature review on theory-driven design research. This list of six journals includes the official journals of the Design Society (*Design Science*, as well as DS-endorsed *Journal of Engineering Design*) and the Design Research Society (*Design Studies*). It includes the four highest rated generalist design journals (Design Studies, Design Issues, Journal of Engineering Design and International Journal of Design, according to the study by Gemser et al. 2012), as well as a journal representing the engineering-leaning side of design research (*Research in Engineering Design*). Of course, this list could be contested: had we included journals such as the *Journal of Mechanical Design*, *CoDesign* or *AI-EDAM*, our results may have changed. For example, we would expect to find elements of stakeholder engagement in most *CoDesign* articles, which would have affected our findings on this dimension. Similarly, the inclusion of conference proceedings (e.g., the Design Society's International Conference on Engineering Design, CIRP Design, or ASME's International Design Engineering Technical Conferences) may have altered our findings. Yet, conferences are often a place to discuss work in progress, and design researchers usually aim to publish final results in journals. Finally, much design research in healthcare may also be unpublished, residing within client

organisations, consultancies or non-academic sources like personal or professional blogs and websites, but we preferred to focus on peer-reviewed academic publications. Although no list of journals will ever be consensual, we believe that the list we used does justice to the diversity of design research (McMahon 2012). In particular, we note a balanced representation of Practice-based design research, Research in design context and Design inclusive research as framing methodologies in our sample of articles.

Second, when planning data extraction, we relied as much as possible on pre-existing categories, to ensure that these categories were fully documented and would not represent our own pre-conceptions of design research. We coded some categories easily (e.g., country of authors' affiliations), but we sometimes struggled with others. Involving three different reviewers in the data extraction stage means that we could raise disagreements and discuss them. Another team may not get exactly the same results, but this is as close as we could get to a reproducible process.

Finally, the nature of our approach means that research that could qualify as "design research" but was published outside of the design research literature (and often performed by researchers outside of what we have implicitly defined as the "design research community"), was not included. The six journals we analysed are not included in PubMed, the leading bibliographic database for health sciences. For example, our sample did not include any article on Experience-Based Co-Design, an approach mostly published in health services research and medical journals (Green et al. 2020). This is consistent with our aim to map what the design research community has produced in relation with healthcare, rather than to identify all published records of application of design approaches in healthcare. For this latter objective, a "traditional" systematic review, searching multiple databases would bridge separations between research communities and aggregate findings (Lamé 2019).

5 Conclusion

In this article, we set out to answer three research questions on the way the design research community engages with the healthcare sector:

- (1) What design concepts and approaches do we apply when studying healthcare?
- (2) Who, in the design research community, works on healthcare?
- (3) What aspects of this human enterprise do we focus on? Which aspects have we left out of our investigations?

To answer these questions, we reviewed healthcare design research published in six key design journals. We did not want to analyse all research conducted in healthcare that includes an element of design, but to map what the design research community does in relation to healthcare. Our conclusions are thus specific to research in healthcare performed by design researchers and communicated to other design researchers. These results do not necessarily apply to the general case of research projects in healthcare that contain an element of design.

In response to Question 1, articles in our sample were mostly applied, with high levels of implementation of the findings and prevalent stakeholder engagement. The three main methodological streams of design research (design inclusive research, research in design context, and practice-based design research) were well represented.

When it comes to Question 2, we found geographical concentration in a few countries, with Denmark, the United States, the United Kingdom, and the Netherlands together accounting for 84% of all articles. The disciplinary backgrounds of authors were balanced between the arts/industrial design and the engineering/technology traditions of design (McMahon 2012), with 27% of articles combining at least two disciplinary

backgrounds. We note that the number of articles is increasing, with half of the articles in our sample published since 2015.

Finally, with regards to Question 3, the focus on products (61% of articles) at the expense of other types of artefacts was striking. Hospitals are the dominant context of application (41%), and most articles focused on upstream stages of the design process (clarification of task, 72%; conceptual design, 50%; and embodiment design, 50%).

Design research is diverse in its methods, its objects, and its conceptual perspectives, and this is also the case in healthcare design research. Nonetheless, a few trends can be observed based upon our results. Some of these trends are very encouraging, such as our commitment to engage with stakeholders. Other patterns indicate areas for future development and diversification, e.g., widening healthcare design's perimeter from the current emphasis on products and hospitals, or engaging researchers from more countries in healthcare design research and promoting interdisciplinary collaborations.

We hope that these results can help the design research community in understanding its current practices and in developing future projects. Given the scope of the challenges and the distinctive strengths design can offer, the future looks promising for healthcare design research.

Declaration of interest

The authors report no conflict of interest for this work.

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Appendix 1. List of articles included in the systematic literature review

- Alexander, K., and P. J. Clarkson. 2002. "A validation model for the medical devices industry." *Journal of Engineering Design* 13 (3):197-204. doi: 10.1080/09544820110108890.
- Aranda-Jan, C. B., S. Jagtap, and J. Moultrie. 2016. "Towards A Framework for Holistic Contextual Design for Low-Resource Settings." *International Journal of Design* 10 (3):43-63.
- Brodersen, S., M. Hansen, and H. Lindegaard. 2015. "Script of Healthcare Technology: Do Designs of Robotic Beds Exclude or Include Users?" *Design Issues* 31 (2):16-28. doi: 10.1162/DESI_a_00319.
- Buskermolen, D. O., J. Terken, B. Eggen, and E. van Loenen. 2015. "Effect of Visual Quality and Animation of Concept Representations on Users' Responses to Early Design Concepts: A Study on the Adaptive Patient Room Concept." *International Journal of Design* 9 (1):91-106.
- Clarkson, P. J. 2018. "What has engineering design to say about healthcare improvement?" *Design Science* 4:35. doi: 10.1017/dsj.2018.13.
- Clarkson, P. J., P. Buckle, R. Coleman, D. Stubbs, J. Ward, J. Jarrett, R. Lane, and J. Bound. 2004. "Design for patient safety: a review of the effectiveness of design in the UK health service." *Journal of Engineering Design* 15 (2):123-40. doi: 10.1080/09544820310001617711.
- Clegg, C. W., M. A. Robinson, M. C. Davis, L. E. Bolton, R. L. Pieniazek, and A. McKay. 2017. "Applying organizational psychology as a design science: A method for predicting malfunctions in socio-technical systems (PreMiSTS)." *Design Science* 3:31. doi: 10.1017/dsj.2017.4.
- De Couvreur, L., W. Dejonghe, J. Detand, and R. Goossens. 2013. "The Role of Subjective Well-Being in Co-Designing Open-Design Assistive Devices." *International Journal of Design* 7 (3):57-70.
- Deiningner, M., S. R. Daly, J. C. Lee, C. M. Seifert, and K. H. Sienko. 2019. "Prototyping for context: exploring stakeholder feedback based on prototype type, stakeholder group and question type." *Research in Engineering Design* 30 (4):453-71. doi: 10.1007/s00163-019-00317-5.

- Eckert, C. M., M. Stacey, D. Wyatt, and P. Garthwaite. 2012. "Change as little as possible: creativity in design by modification." *Journal of Engineering Design* 23 (4):337-60. doi: 10.1080/09544828.2011.639299.
- Glover, J., and K. Daniels. 2017. "An exploratory study into everyday problem solving in the design process of medical devices." *Journal of Engineering Design* 28 (10-12):821-43. doi: 10.1080/09544828.2017.1397269.
- Hagedorn, T. J., B. Smith, S. Krishnamurty, and I. Grosse. 2019. "Interoperability of disparate engineering domain ontologies using basic formal ontology." *Journal of Engineering Design* 30 (10-12):625-54. doi: 10.1080/09544828.2019.1630805.
- Hahn, B., and C. Zimmermann. 2011. "Visualizing Daily Hospital Routine." *Design Issues* 27 (3):72-83. doi: 10.1162/DESI_a_00092.
- Hargraves, I. 2018. "Care and Capacities of Human-Centered Design." *Design Issues* 34 (3):76-88. doi: 10.1162/desi_a_00498.
- Hoiseth, M., and M. M. Keitsch. 2015. "Using Phenomenological Hermeneutics to Gain Understanding of Stakeholders in Healthcare Contexts." *International Journal of Design* 9 (3):33-45.
- Kanstrup, A. M. 2014. "Design Concepts for Digital Diabetes Practice: Design to Explore, Share, and Camouflage Chronic Illness." *International Journal of Design* 8 (3):49-60.
- Kasali, A., and N. J. Nersessian. 2015. "Architects in interdisciplinary contexts: Representational practices in healthcare design." *Design Studies* 41:205-23. doi: 10.1016/j.destud.2015.09.001.
- Kelly, J., and B. Matthews. 2014. "Displacing use: Exploring alternative relationships in a human-centred design process." *Design Studies* 35 (4):353-73. doi: 10.1016/j.destud.2014.02.001.
- Kelly, J., and S. A. G. Wensveen. 2014. "Designing to Bring the Field to the Showroom through Open-ended Provocation." *International Journal of Design* 8 (2):71-85.
- Kleinsmann, M., and M. ten Bhomer. 2020. "The (New) Roles of Prototypes During the Co-Development of Digital Product Service Systems." *International Journal of Design* 14 (1):65-79.
- Lee, S. 2011. "Evaluating Serviceability of Healthcare Servicescapes: Service Design Perspective." *International Journal of Design* 5 (2):61-71.

- Lehoux, P., M. Hivon, B. Williams-Jones, and D. Urbach. 2011. "The worlds and modalities of engagement of design participants: A qualitative case study of three medical innovations." *Design Studies* 32 (4):313-32. doi: 10.1016/j.destud.2011.01.001.
- Li, C., C. F. Lee, and S. Xu. 2020. "Stigma Threat in Design for Older Adults: Exploring Design Factors that Induce Stigma Perception." *International Journal of Design* 14 (1):51-64.
- Lin, M. C., B. L. Hughes, M. K. Katica, C. Dining-Zuber, and P. E. Plsek. 2011. "Service Design and Change of Systems: Human-Centered Approaches to Implementing and Spreading Service Design." *International Journal of Design* 5 (2):73-86.
- Markussen, T. 2009. "Bloody Robots as Emotional Design: How Emotional Structures May Change Expectations of Technology Use in Hospitals." *International Journal of Design* 3 (2):27-39.
- Medina, L. A., G. E. O. Kremer, and R. A. Wysk. 2013. "Supporting medical device development: a standard product design process model." *Journal of Engineering Design* 24 (2):83-119. doi: 10.1080/09544828.2012.676635.
- Moller, T., and S. Kettley. 2017. "Wearable Health Technology Design: A Humanist Accessory Approach." *International Journal of Design* 11 (3):35-49.
- Mullaney, T., H. Pettersson, T. Nyholm, and E. Stolterman. 2012. "Thinking beyond the Cure: A Case for Human-Centered Design in Cancer Care." *International Journal of Design* 6 (3):27-39.
- Onarheim, B. 2012. "Creativity from constraints in engineering design: lessons learned at Coloplast." *Journal of Engineering Design* 23 (4):323-36. doi: 10.1080/09544828.2011.631904.
- Onarheim, B., and B. T. Christensen. 2012. "Distributed idea screening in stage-gate development processes." *Journal of Engineering Design* 23 (9):660-73. doi: 10.1080/09544828.2011.649426.
- Ostergaard, K. L., J. Simonsen, and H. Karasti. 2018. "Examining situated design practices: Nurses' transformations towards genuine participation." *Design Studies* 59:37-57. doi: 10.1016/j.destud.2017.12.002.
- Park, J. H. 2015. "Health Care Design: Current and Potential Research and Development." *Design Issues* 31 (1):63-72. doi: 10.1162/DESI_a_00310.

- Patou, F., N. Ciccone, J. Thorpe, and A. Maier. 2020. "Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?" *Journal of Engineering Design* 31 (7):379-98. doi: 10.1080/09544828.2020.1763272.
- Pedersen, S. N., M. E. Christensen, and T. J. Howard. 2016. "Robust design requirements specification: a quantitative method for requirements development using quality loss functions." *Journal of Engineering Design* 27 (8):544-67. doi: 10.1080/09544828.2016.1183163.
- Petersen, T. B., and V. Riisberg. 2016. "Pockets, Buttons and Hangers: Designing a New Uniform for Health Care Professionals." *Design Issues* 32 (1):60-71. doi: 10.1162/DESI_a_00365.
- Pierri, P. 2018. "Participatory Design Practices in Mental Health in the UK: Rebutting the Optimism." *Design Issues* 34 (4):25-36. doi: 10.1162/desi_a_00509.
- Roesler, A., E. B. Grigg, L. D. Martin, F. J. Ross, M. Feil, S. E. Rampersad, C. M. Haberkern, and L. D. Martin. 2019. "Practice-Centered Design of an Anesthesia Medication Template to Reduce Medication Handling Errors in the Operating Room." *International Journal of Design* 13 (1):53-68.
- Tobiasson, H., Y. Sundblad, A. Walldius, and A. Hedman. 2015. "Designing for Active Life: Moving and Being Moved Together with Dementia Patients." *International Journal of Design* 9 (3):47-62.
- Tzortzopoulos, P., R. Cooper, P. Chan, and M. Kagioglou. 2006. "Clients' activities at the design front-end." *Design Studies* 27 (6):657-83. doi: 10.1016/j.destud.2006.04.002.
- van Amstel, F. M. C., T. Hartmann, M. C. van der Voort, and Gpmr Dewulf. 2016. "The social production of design space." *Design Studies* 46:199-225. doi: 10.1016/j.destud.2016.06.002.
- van Stralen, D. 2008. "High-reliability organizations: Changing the culture of care in two medical units (The Pediatric Intensive Care Unit (PICU))." *Design Issues* 24 (1):78-90. doi: 10.1162/desi.2008.24.1.78.
- Vukasinovic, N., T. Kolsek, and J. Duhovnik. 2007. "Case Study - surface reconstruction from point clouds for prosthesis production." *Journal of Engineering Design* 18 (5):475-88. doi: 10.1080/09544820701403805.
- Weightman, A. P. H., N. Preston, R. Holt, M. Allsop, M. Levesley, and B. Bhakta. 2010. "Engaging children in healthcare technology design: developing

rehabilitation technology for children with cerebral palsy." *Journal of Engineering Design* 21 (5):579-600. doi: 10.1080/09544820802441092.

Ziegler, U. 2015. "Multi-Sensory Design as a Health Resource: Customizable, Individualized, and Stress-Regulating Spaces." *Design Issues* 31 (1):53-62. doi: 10.1162/DESI_a_00309.

Appendix 2. Detailed categories for data extraction.

Theme	Category	Possible options
Article characteristics	Discipline	<ul style="list-style-type: none"> - Humanities and liberal arts - Social and behavioral sciences - Natural sciences - Human professions and services - Technology and engineering - Applied arts, design and architecture - Medical and health sciences - Company - Not classifiable
	Country of affiliation of authors	<ul style="list-style-type: none"> - Any country, based on the authors' affiliations
	Article methodology	<ul style="list-style-type: none"> - Conceptual article - Opinion article - Literature review - Empirical article
Design-related themes	Design categories	<ul style="list-style-type: none"> - Human assets (design psychology, design cognition, design ethnography, design aesthetics, design ergonomics, product marketing) - Design knowledge (design epistemology, design intelligence, design externalization, design education) - Artifact knowledge (technical systems, product principles, artifacts manifestations) - Processes knowledge (design processes, artifactual processes, implicated processes) - Design application (design praxeology, design assurance, design standardization, design sustenance, design management) - Design philosophy (design science, design history, design policy, design ethics, design axiology)

		<ul style="list-style-type: none"> - Design technology (design informatics, design languages, design mindware, design software, design hardware, design systems) - Design theory (design theories, design semantics, design systematization) - Design methodology (methodology of design, design innovation, design modeling, modeling technics)
	Framing methodology	<ul style="list-style-type: none"> - Research in design context - Design inclusive research - Practice base design research
	Level of implementation	<ul style="list-style-type: none"> - Real problem solving - Hypothetical problem solving - Methodological article - No problem solving intention
	Life cycle stage	<ul style="list-style-type: none"> - Clarification of task - Conceptual design - Embodiment design - Detail design - Manufacture - Usage - End of life
Healthcare-related themes	Artifact studied	<ul style="list-style-type: none"> - Device - Service and service product - Organization / Process - Architecture / Space and built environment
	Application sector	<ul style="list-style-type: none"> - Primary care - Home and community care - Hospital care - Not classifiable - Medical device industry

		<ul style="list-style-type: none"> - Healthcare system
	Specialty at stake	<ul style="list-style-type: none"> - Mental Health - Surgery and anesthesiology - Medicine (includes primary care and intensive care) - Laboratory test - Not classifiable
	Type of health condition	<ul style="list-style-type: none"> - Acute - Chronic - Both chronic and acute (includes cancer) - NA - Prevention
	Stakeholders engaged	<ul style="list-style-type: none"> - Designers, engineers and architects - Patients (including pre-users) and relatives - Health care professionals - Managers - None - Industry (excluding designers)

References

- Alexander, Karen, and P. John Clarkson. 2002. "A validation model for the medical devices industry." *Journal of Engineering Design* 13 (3):197-204. doi: 10.1080/09544820110108890.
- Altman, Myra, Terry T. K. Huang, and Jessica Y. Breland. 2018. "Design Thinking in Health Care." *Preventing chronic disease* 15:E117-E. doi: 10.5888/pcd15.180128.
- Ancker, Jessica S, Holly O Witteman, Baria Hafeez, Thierry Provencher, Mary Van de Graaf, and Esther Wei. 2015. "The Invisible Work of Personal Health Information Management Among People With Multiple Chronic Conditions: Qualitative Interview Study Among Patients and Providers." *Journal of Medical Internet Research* 17 (6):e137. doi: 10.2196/jmir.4381.
- Batalden, Maren, Paul Batalden, Peter Margolis, Michael Seid, Gail Armstrong, Lisa Opipari-Arrigan, and Hans Hartung. 2016. "Coproduct of healthcare service." *BMJ Quality & Safety* 25 (7):509-17. doi: 10.1136/bmjqs-2015-004315.
- Bauer, Ursula E., Peter A. Briss, Richard A. Goodman, and Barbara A. Bowman. 2014. "Prevention of chronic disease in the 21st century: elimination of the leading preventable causes of premature death and disability in the USA." *The Lancet* 384 (9937):45-52. doi: 10.1016/S0140-6736(14)60648-6.
- Blackburn, Steven, Sarah McLachlan, Sue Jowett, Philip Kinghorn, Paramjit Gill, Adele Higginbottom, Carol Rhodes, Fiona Stevenson, and Clare Jinks. 2018. "The extent, quality and impact of patient and public involvement in primary care research: a mixed methods study." *Research Involvement and Engagement* 4 (1):16. doi: 10.1186/s40900-018-0100-8.
- Bradbury-Jones, Caroline, Jenna P. Breckenridge, Maria T. Clark, Oliver R. Herber, Christine Jones, and Julie Taylor. 2019. "Advancing the science of literature reviewing in social research: the focused mapping review and synthesis." *International Journal of Social Research Methodology*:1-12. doi: 10.1080/13645579.2019.1576328.
- Brodersen, Søsner, Meiken Hansen, and Hanne Lindegaard. 2015. "Script of Healthcare Technology: Do Designs of Robotic Beds Exclude or Include Users?" *Design Issues* 31 (2):16-28. doi: 10.1162/DESI_a_00319.
- Brown, Julie C., Rachel E. Tuuri, Sabreen Akhter, Lilia D. Guerra, Ian S. Goodman, Sage R. Myers, Charles Nozicka, et al. 2016. "Lacerations and Embedded Needles Caused by Epinephrine Autoinjector Use in Children." *Annals of Emergency Medicine* 67 (3):307-15.e8. doi: 10.1016/j.annemergmed.2015.07.011.
- Buchanan, Richard. 2001. "Design research and the new learning." *Design issues* 17 (4):3-23.
- Buskermolen, Derya Ozcelik, Jacques Terken, Berry Eggen, and Evert van Loenen. 2015. *Effect of Visual Quality and Animation of Concept Representations on Users' Responses to Early Design Concepts: A Study on the Adaptive Patient Room Concept, 2015*.
- Callahan, Jamie L. 2010. "Constructing a Manuscript: Distinguishing Integrative Literature Reviews and Conceptual and Theory Articles." *Human Resource Development Review* 9 (3):300-4. doi: 10.1177/1534484310371492.
- Cash, Philip, Ben Hicks, Steve Culley, and Tim Adlam. 2015. "A foundational observation method for studying design situations." *Journal of Engineering Design* 26 (7-9):187-219. doi: 10.1080/09544828.2015.1020418.
- Cash, Philip J. 2018. "Developing theory-driven design research." *Design Studies* 56:84-119. doi: 10.1016/j.destud.2018.03.002.
- Christensen, Bo T., and Linden J. Ball. 2019. "Building a discipline: Indicators of expansion, integration and consolidation in design research across four decades." *Design Studies* 65:18-34. doi: 10.1016/j.destud.2019.10.001.
- Clarkson, P. John. 2018. "What has engineering design to say about healthcare improvement?" *Design Science* 4:e17. doi: 10.1017/dsj.2018.13.
- Clarkson, P. John, P. Buckle, R. Coleman, D. Stubbs, J. Ward, J. Jarrett, R. Lane, and J. Bound. 2004. "Design for patient safety: A review of the effectiveness of design in the UK health service." *Journal of Engineering Design* 15 (2):123-40. doi: 10.1080/09544820310001617711.
- Deiningner, Michael, Shanna R. Daly, Jennifer C. Lee, Colleen M. Seifert, and Kathleen H. Sienko. 2019. "Prototyping for context: exploring stakeholder feedback based on prototype type, stakeholder group and question type." *Research in Engineering Design* 30 (4):453-71. doi: 10.1007/s00163-019-00317-5.
- Doraiswamy, Sathyanarayanan, Amit Abraham, Ravinder Mamtani, and Sohaila Cheema. 2020. "Use of Telehealth During the COVID-19 Pandemic: Scoping Review." *J Med Internet Res* 22 (12):e24087. doi: 10.2196/24087.
- Eckert, Claudia M., Martin Stacey, David Wyatt, and Pam Garthwaite. 2012. "Change as little as possible: creativity in design by modification." *Journal of Engineering Design* 23 (4):337-60. doi: 10.1080/09544828.2011.639299.
- Frenk, Julio. 2009. "Reinventing primary health care: the need for systems integration." *The Lancet* 374 (9684):170-3. doi: 10.1016/S0140-6736(09)60693-0.
- Gemser, Gerda, Cees de Bont, Paul Hekkert, and Ken Friedman. 2012. "Quality perceptions of design journals: The design scholars' perspective." *Design Studies* 33 (1):4-23. doi: 10.1016/j.destud.2011.09.001.
- Gilson, Lucy L., and Caren B. Goldberg. 2015. "Editors' Comment: So, What Is a Conceptual Paper?" *Group & Organization Management* 40 (2):127-30. doi: 10.1177/1059601115576425.

- Gough, David, and James Thomas. 2017. "Introducing systematic reviews." In *An introduction to systematic reviews*, edited by David Gough, Sandy Oliver and James Thomas, 1-17. Los Angeles: SAGE.
- Gray, Muir. 2016. "Designing healthcare for a different future." *Journal of the Royal Society of Medicine* 109 (12):453-8. doi: 10.1177/0141076816679781.
- Green, Theresa, Ann Bonner, Laisa Teleni, Natalie Bradford, Louise Purtell, Clint Douglas, Patsy Yates, Margaret MacAndrew, Hai Yen Dao, and Raymond Javan Chan. 2020. "Use and reporting of experience-based codesign studies in the healthcare setting: a systematic review." *BMJ Quality & Safety* 29 (1):64-76. doi: 10.1136/bmjqs-2019-009570.
- Guzzo, D., M. M. Carvalho, R. Balkenende, and J. Mascarenhas. 2020. "Circular business models in the medical device industry: paths towards sustainable healthcare." *Resources, Conservation and Recycling* 160:104904. doi: 10.1016/j.resconrec.2020.104904.
- Hargraves, Ian. 2018. "Care and Capacities of Human-Centered Design." *Design Issues* 34 (3):76-88. doi: 10.1162/desi_a_00498.
- Høiseth, Marikken, and Martina Maria Keitsch. 2015. *Using Phenomenological Hermeneutics to Gain Understanding of Stakeholders in Healthcare Contexts, 2015*.
- Horváth, Imre. 2004. "A treatise on order in engineering design research." *Research in Engineering Design* 15 (3):155-81. doi: 10.1007/s00163-004-0052-x.
- . 2007. Comparison of three methodological approaches of design research. Paper presented at the DS 42: Proceedings of ICED 2007, the 16th International Conference on Engineering Design, Paris, France, 28.-31.07. 2007.
- . 2008. "Differences between 'research in design context' and 'design inclusive research' in the domain of industrial design engineering." *Journal of Design Research* 7 (1):61. doi: 10.1504/jdr.2008.018777.
- Jahangirian, Mohsen, Aisha Naseer, Lampros Stergioulas, Terry Young, Tillal Eldabi, Sally C. Brailsford, Brijesh Patel, and Paul Harper. 2012. "Simulation in health-care: lessons from other sectors." *Operational Research* 12 (1):45-55. doi: 10.1007/s12351-010-0089-8.
- Kasali, Altug, and Nancy J. Nersessian. 2015. "Architects in interdisciplinary contexts: Representational practices in healthcare design." *Design Studies* 41:205-23. doi: 10.1016/j.destud.2015.09.001.
- Kelly, Janet, and Ben Matthews. 2014. "Displacing use: Exploring alternative relationships in a human-centred design process." *Design Studies* 35 (4):353-73. doi: 10.1016/j.destud.2014.02.001.
- Kelly, Janet, and Stephan Wensveen. 2014. *Designing to Bring the Field to the Showroom through Open-ended Provocation, 2014*.
- Komashie, Alexander, Guillaume Lamé, Francois Patou, Nicholas Ciccone, Anja Maier, and P. John Clarkson. 2019. "Exploring healthcare systems design research and practice: outcomes of an international meeting." In *ICED19 - The 22nd International Conference on Engineering Design*. Delft: Design Society.
- Kriznik, Natasha Marie, Guillaume Lamé, and Mary Dixon-Woods. 2019. "Challenges in making standardisation work in healthcare: lessons from a qualitative interview study of a line-labelling policy in a UK region." *BMJ Open* 9 (11):e031771. doi: 10.1136/bmjopen-2019-031771.
- Lamé, Guillaume. 2019. "Systematic literature reviews: an introduction." In *ICED19 - 22nd International Conference on Engineering Design*. Delft: Design Society.
- Lee, Seunghae. 2011. *Evaluating Serviceability of Healthcare Servicescapes: Service Design Perspective, 2011*.
- Lehoux, Pascale, Myriam Hivon, Bryn Williams-Jones, and David Urbach. 2011. "The worlds and modalities of engagement of design participants: A qualitative case study of three medical innovations." *Design Studies* 32 (4):313-32. doi: 10.1016/j.destud.2011.01.001.
- Lin, Michael, Bobby Hughes, Mary Katica, Christi Zuber, and Paul Plsek. 2011. *Service Design and Change of Systems: Human-Centered Approaches to Implementing and Spreading Service Design, 2011*.
- Markussen, Thomas. 2009. *Bloody Robots as Emotional Design: How Emotional Structures May Change Expectations of Technology Use in Hospitals, 2009*.
- Mathews, Simon C., and Peter J. Pronovost. 2011. "The Need for Systems Integration in Health Care." *JAMA* 305 (9):934. doi: 10.1001/jama.2011.237.
- McLaughlin, Jacqueline E., Michael D. Wolcott, Devin Hubbard, Kelly Umstead, and Traci R. Rider. 2019. "A qualitative review of the design thinking framework in health professions education." *BMC Medical Education* 19 (1):98. doi: 10.1186/s12909-019-1528-8.
- McMahon, C. A. 2012. "Reflections on diversity in design research." *Journal of Engineering Design* 23 (8):563-76. doi: 10.1080/09544828.2012.676634.
- Ocloo, Josephine, and Rachel Matthews. 2016. "From tokenism to empowerment: progressing patient and public involvement in healthcare improvement." *BMJ Quality & Safety* 25 (8):626-32. doi: 10.1136/bmjqs-2015-004839.
- OECD. 2021. "OECD Health Statistics 2021." Accessed 15 Oct. <https://www.oecd.org/els/health-systems/health-data.htm>.
- Oliveira, Mariana, Eduardo Zancul, and André Leme Fleury. 2021. "Design thinking as an approach for innovation in healthcare: systematic review and research avenues." *BMJ Innovations* 7 (2):491-8. doi: 10.1136/bmjinnov-2020-000428.

- Onarheim, Balder. 2012. "Creativity from constraints in engineering design: lessons learned at Coloplast." *Journal of Engineering Design* 23 (4):323-36. doi: 10.1080/09544828.2011.631904.
- Østergaard, Kija Lin, Jesper Simonsen, and Helena Karasti. 2018. "Examining situated design practices: Nurses' transformations towards genuine participation." *Design Studies* 59:37-57. doi: 10.1016/j.destud.2017.12.002.
- Page, Matthew J, Joanne E McKenzie, Patrick M Bossuyt, Isabelle Boutron, Tammy C Hoffmann, Cynthia D Mulrow, Larissa Shamseer, et al. 2021. "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews." *BMJ* 372:n71. doi: 10.1136/bmj.n71.
- Pahl, G., and Wolfgang Beitz. 1996. *Engineering design: a systematic approach*. London ; New York, NY: Springer.
- Papalambros, Panos Y., Saeema Ahmed-Kristensen, Petra Badke-Schaub, Kristi Bauerly, Jean-François Boujut, Jonathan Cagan, Marco Cantamessa, et al. 2015. "Design Science: Why, What and How." *Design Science* 1. doi: 10.1017/dsj.2015.1.
- Patou, François, Nicholas Ciccone, Julia Thorpe, and Anja Maier. 2020. "Designing P4 healthcare interventions for managing cognitive decline and dementia: where are we at?" *Journal of Engineering Design*:1-20. doi: 10.1080/09544828.2020.1763272.
- Petersen, Trine Brun, and Vibeke Riisberg. 2016. "Pockets, Buttons and Hangers: Designing a New Uniform for Health Care Professionals." *Design Issues* 32 (1):60-71. doi: 10.1162/DESI_a_00365.
- Reeson, Marc, Kwadwo Kyeremanteng, and Gianni D'Egidio. 2018. "Defibrillator Design and Usability May Be Impeding Timely Defibrillation." *The Joint Commission Journal on Quality and Patient Safety* 44 (9):536-44. doi: 10.1016/j.jcjq.2018.01.005.
- Schettkat, Ronald, and Lara Yocarini. 2006. "The shift to services employment: A review of the literature." *Structural Change and Economic Dynamics* 17 (2):127-47. doi: 10.1016/j.strueco.2005.04.002.
- Smye, Stephen W, and Alejandro F Frangi. 2021. "Interdisciplinary research: shaping the healthcare of the future." *Future Healthcare Journal* 8 (2):e218-e23. doi: 10.7861/fhj.2021-0025.
- Snider, C., S. Škec, J. A. Gopsill, and B. J. Hicks. 2017. "The characterisation of engineering activity through email communication and content dynamics, for support of engineering project management." *Design Science* 3:e22. doi: 10.1017/dsj.2017.16.
- Tobiasson, Helena Margareta, Yngve Sundblad, Åke Walldius, and Anders Hedman. 2015. *Designing for Active Life: Moving and Being Moved Together with Dementia Patients, 2015*.
- van Stralen, Daved M. D. 2008. "High-Reliability Organizations: Changing the Culture of Care in Two Medical Units." *Design Issues* 24 (1):78-90. doi: 10.1162/desi.2008.24.1.78.
- Vigo, Daniel, Graham Thornicroft, and Rifat Atun. 2016. "Estimating the true global burden of mental illness." *The Lancet Psychiatry* 3 (2):171-8. doi: 10.1016/S2215-0366(15)00505-2.
- Vukašinić, N., T. Kolšek, and J. Duhovnik. 2007. "Case Study – surface reconstruction from point clouds for prosthesis production." *Journal of Engineering Design* 18 (5):475-88. doi: 10.1080/09544820701403805.
- Wears, Robert L., and Rollin J. Fairbanks. 2016. "Design Trumps Training." *Annals of Emergency Medicine* 67 (3):316-7. doi: 10.1016/j.annemergmed.2015.10.014.
- Williams, Oli, Sophie Sarre, Stan Constantina Papoulias, Sarah Knowles, Glenn Robert, Peter Beresford, Diana Rose, Sarah Carr, Meerat Kaur, and Victoria J. Palmer. 2020. "Lost in the shadows: reflections on the dark side of co-production." *Health Research Policy and Systems* 18 (1):43. doi: 10.1186/s12961-020-00558-0.
- Xing, Ke, Mario Rapaccini, and Filippo Visintin. 2017. "PSS in Healthcare: An Under-Explored Field." *Procedia CIRP* 64:241-6. doi: 10.1016/j.procir.2017.03.068.
- Ziegler, Ute. 2015. "Multi-Sensory Design as a Health Resource: Customizable, Individualized, and Stress-Regulating Spaces." *Design Issues* 31 (1):53-62. doi: 10.1162/DESI_a_00309.