Design-Driven Approaches for Enhanced Antibiogram Utilization: A review of User-Centered Design Methodologies with Clinical Expertise

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Abstract. User-centered design (UCD) methodologies are focused on creating solutions adapted to the specific needs and contexts of targeted users. Such practices are especially critical in healthcare settings, where the quality, accessibility, adaptability and usability of diagnostic and treatment tools significantly impact patient outcomes. A key diagnostic tool in clinical practice is the antibiogram, which presents sensitivity test results for microorganisms against various antibiotic concentrations. Interpreting antibiogram results requires customization based on individual clinical factors, adding complexity to the decision-making process in antibiotic therapy. This scoping review aims to improve healthcare research projects, such as the optimization of antibiogram-directed antibiotic therapy, by taking into account the needs of all stakeholders involved. Our contribution provides a critical and descriptive analysis of the application of various user-centered design (UCD) methods within healthcare settings and outlines validated methods used in the collection and analysis of data from healthcare studies employing these methodologies. Additionally, the review offers detailed practical application guidelines to assist other researchers in their implementation.

Keywords: User-Centered Design, Service Design, Design Methodology, Healthcare, Health Services, Decision-Making Support.

1 Introduction

1.1 User-centered design methodologies in healthcare

The traditional, evidence-based health services research (HSR) methods are commonly used for the execution of health projects. HSR methods guide rigorous and effective interventions that prioritize compliance with technical specifications, dissemination, and scalability of the proposed solution [1]. The implementation of interventions can be challenging because end users may need to adapt them to suit their unique circumstances. This is often due to a lack of human-centered or participatory approaches during the design process. As a result, end users may not have been able to provide input that would have made the interventions more

effective for their needs. To implement these strategies and ensure their acceptance among all parties, there is a growing methodological trend to facilitate the development and evolution of healthcare through a human-centered approach [1, 2, 3] (i.e., human-centered design 'HCD' or user-centered design 'UCD' methodologies). Through repeated prototyping and iterative refinement of the proposed solution, the new products, services, and experiences are designed to address the needs of the target audience. This places the focus of project activities on the target audience rather than on the material and technological characteristics of the product or service [4].

Applying the principles of human-centered design, the Design Thinking methodology describes the entire design process by dividing it into 5 distinct steps: (1) *Discover*: empathize with the end user and understand their context and needs; (2) *Define*: identify and define the problem through a point of view shared by the different stakeholders; (3) *Ideate*: generate innovative ideas to satisfy the defined problem through a multidisciplinary group formed by experts and end users; (4) *Prototyping*: materialize the solutions by developing prototypes; (5) *Testing*: evaluate the prototypes iteratively to obtain feedback from the end user and gradually bring the solution closer to the final version that best meets their needs [5]. A different methodology, the Double Diamond approach [6] describes the design process in four stages: *Discover*, *Define*, *Develop* and *Deliver*. The Double Diamond methodology uses two diamonds that represent the design process as a change flow from divergent to convergent thinking, reflecting the transition from the exploration to the realization phases [6]. In comparison with Design Thinking, this methodology includes in the Develop phase the ideation and prototyping and in the Deliver phase the usability testing of the solution and its implementation.

Both methodologies have in common the use of co-design processes and methodologies as a key approach strategy in all the phases of a project. Co-design is a collective activity that enhances creativity through the formation of interdisciplinary groups, composed by designers as well as by people without knowledge of design methodologies. The goal of these methodologies is to include both perspectives in the different processes that make up a project [7]. The application of this perspective in the design of healthcare strategies allows understanding and taking into consideration the personal experiences and needs of users, including patients and clinical staff [3]: co-design processes increase the chances of satisfying clinicians and patients and ensuring the acceptance of the strategy developed in the healthcare environment [8], as well as promoting health equity thanks to the in-depth knowledge of the context, needs, and demands of these users [9]. For this reason, numerous initiatives are being developed to familiarize these professionals with human-centered design approaches [10].

These initiatives align with healthcare professionals' patient-centeredness from a collaborative, multidisciplinary perspective and user experience as synonymous with increased quality and improved healthcare delivery [12, 13, 14]. However, healthcare professionals still face several challenges when implementing these approaches in healthcare [11]. While research encouraging user participation in the healthcare environment is increasing, it tends to leave the user in a passive, one-way listening

position. This, together with the limited description of existing design processes in the literature, evidences a marked need for training of research staff in user-centered design methodologies [14, 15]. To alleviate this challenge, we present a review of existing UCD methods and analyze how co-design processes can be applied in the initial stages of a project.

1.2 User-centered design methodologies in the applied domain of antibiotic prescription

The ultimate goal of this work is to find UCD methodologies to improve and optimize the usability of the antibiogram, a diagnostic tool that collects efficacy and resistance therapeutic results of antibiotics against bacteria [16]. We believe that a correct analysis and design of the antibiogram could increase the quality and accuracy of antibiotic prescribing. Our work follows the current trend of not only investigating the development of new drugs but also pursuing other strategies such as the development of clinical decision support systems [17, 18, 19]. In the development of these strategies, there is a perceived need to customize these tools to adapt them to the specific situations of each patient by applying innovative methods, which also include and take into consideration healthcare professionals and train them for the digital environment [17, 18]. Moreover, the effectiveness of these interventions in terms of practical functionality and implementation fidelity is closely tied to how well they are tailored to fit the organizational and social characteristics of the clinical setting and the standard procedures of healthcare professionals [20]. This underscores the importance of integrating user-centered design into the early stages of e.g., the antibiogram's development, focusing on understanding user needs and establishing design criteria, rather than limiting its application to later stages of development and evaluation [17, 21].

The purpose of this review is to carry out a critical, descriptive analysis of how different design UCD methodologies are applied in the healthcare environment. In this initial phase, we are focused on compiling and analyzing qualitative methodologies that are commonly used in the first design phase, which is centered on identifying and analyzing the needs of the end-users. The study of how these methodologies are applied is of high relevance given the complexity of integrating the different perspectives of citizens, patients, and healthcare professionals. Additionally, an inclusive approach is needed, both to achieve an improvement in healthcare quality and towards an effective implementation of the interventions, due to a higher acceptance and adherence of the target public. For these reasons, establishing a guide that facilitates the development of the initial phase of a research project would move healthcare researchers, engineers, designers, and physicians toward the settlement of methodological bases. This knowledge would also increase the familiarity with well-known, established, and validated methodologies of the state-of-the-art literature. Our main contribution is a map of validated methods used in the compilation and analysis of data from studies that apply UCD or HCD methodologies. We do not merely present a list of existing tools, instead, we deepen their practical application indications to facilitate their use by other researchers.

2 Methodology

We have selected a scoping review as a method to gather information since it is useful for identifying and mapping the scope and nature of the available knowledge in the state-of-the-art literature for a particular research topic [22].

2.1 Search Strategy

Three different relevant databases have been selected for the research in the fields of engineering, design and medicine. The selected databases are *Web of Science*, *PubMed* and *Scopus*. Two exposures were carried out: a general search and a specific search.

General search. The goal of this first review is to know the overall status of how UCD or HCD methodologies are applied in a healthcare context to identify which validated methods are used in qualitative research. The keywords for this review have been: *Service Design; Healthcare; Design Methodology* and *User-Centered Design*. The output of this search consisted of 403 records: Web of Science (n=46), PubMed (n=298) and Scopus (n=59).

Specific search. The goal of the second review is to narrow down the search, carrying out a mapping of the application of the design methods in the development of assistance systems for antibiotic prescription. This second review establishes the foundation over which research and development will be carried out to optimize antibiotic therapy through the antibiogram design. The keywords for this review have been: *User-Centered Design* and *Antibiotic Decision Support*. The output of this search consisted of 32 records: Web of Science (n=10), PubMed (n=10) and Scopus (n=12).

Both searches used the Boolean term AND to narrow the results.

2.2 Selection of Sources

General search. Article inclusion criteria were the following: (a) use of design methods in healthcare, (b) written in English, (c) published in last 5 years (2019-2024), (d) journal articles, (e) published in high impact journals (Q1 or Q2). The duplicated articles (n=14) and those not meeting the inclusion criteria (n=369) were excluded from the analysis of this work.

Specific search. Article inclusion criteria were the following: (a) specific clinical decision support tools for antibiotic therapy, (b) written in English, (c) use of user-centered design approach. The duplicated articles (n=8) and those not meeting the inclusion criteria (n=16) were excluded from the investigation. An additional record, identified through other sources, was included since it was considered of special interest for the research.

2.3 Data Extraction

General search. We extract information from a total of 20 works. From there, we gather the journal, goal and purpose, design methodologies applied in the research, data collection methodology, participants typology and samples and other considerations of interest.

Specific search. We extract information from a total of 8 works. From there, we gather the journal, goal and purpose, design methodologies applied in the research, data collection methodology, participants' typology and samples, name and description of the prototypes for antibiotic prescription assistance and other considerations of interest.

75% of the analyzed articles (General Search + Specific Search) are *Original Research* works. Regarding the journal categories, they are generally evenly distributed between *Medicine* and *Design, Engineering or Clinical Informatics* with 8% of articles in medical journals (see Table 1).

Table 1. Categorization of the articles included in the analysis.

Search	Articles Types	Journals Categories
General Search	Original Research (n=13); Review (n=5); Study Protocol (n=2)	Medicine (n=14); Design / Engineering / Clinical Informatics (n=6)
Specific Search	Original Research (n=8)	Medicine (n=1); Design / Engineering / Clinical Informatics (n=7)
% Global Articles	Original Research (75%); Review (18%); Study Protocol (7%)	Medicine (54%); Design / Engineering / Clinical Informatics (46%)

3 Results

The findings have been organized into 2 parts: one of them corresponds to the *general search* and the second to the *specific search*. Within these two sections, we first report the methods presented in the analyzed articles and then we include relevant case studies that show the applicability of the design methodology in a real scenario.

3.1 General search: Which design methods have been applied in healthcare?

In this subsection, we discuss all the methods retrieved through the *general search* and include case studies where these design methods have been applied in the applied domain of healthcare.

General description of the methods. The more general feature of the identified methods is a qualitative-descriptive methodology which leads to gaining insight knowledge as an answer to research questions. It is important to note that involving

stakeholders through co-design procedures is another common methodological factor in these studies [3, 13]. In particular, these are the two co-design tools more frequently used in the first phase of the design process: (1) clinical environment observations to understand the interaction between users and the health service interface; (2) structured and semi-structured interviews and focus groups (FGs) to contextualize and detail the needs of the project, considering all the perspectives and establishing the common touchpoints between studies (we define a *touchpoint* as a critical moment in the experience of the user with the service) [8, 12, 23]. Another common tool is the Persona method, a non-participative analysis technique that seeks to identify target users and place their actions within a given context. This method helps in making informed decisions about the structure and design of a project. The Persona method is also used to create fictional archetypes from the categorization and characterization of real users [24].

The profiles of participants involved in this research typically include healthcare professionals (mainly attending physicians, residents, and nurses), patients, and family members or caregivers. In the reviewed works, the recruitment of patients and professionals is carried out at the hospital or healthcare where the research is taking place, and family members or caregivers are recruited through contact with the patients. The recruitment procedure is similar across different works: (1) Potential collaborators are provided with information about the research in writing or both verbally and in writing; (2) Space is provided for questions and doubts; (3) Informed consent is obtained from the participant, either verbally or in writing, which is the preferred option [13, 25, 26, 27, 28]. Remote contact with participants during the study is typically made via mobile phone, WhatsApp, and email [8, 26, 27].

Field observations. Field observations reported in the literature are characterized by being protocolized through the structured definition of the evaluation criteria. Field observations can be categorized as participatory or non-participative. There is a lot of variability regarding how much time was devoted to field observations in the methods of the general search, with a range from 2 to 80 hours [12]. Field observations are usually analyzed through *qualitative content analysis,* a method suitable for descriptive qualitative analysis [25] which focuses on the theme and the context to explore in depth the differences between categories and codes. It studies both what the text says literally and the themes it speaks about, perceived in the latent content of the text [29].

Interviews. The total number of structured or semistructured interviews conducted in the general search studies varies in a range from 15 to 30 participants, with an equitable representation of each profile. The interviews are conducted face-to-face, online, or by telephone. The interviews take place in private settings and are conducted individually with each participant, typically lasting between 30 and 40 minutes. Documentation is collected through voice recording followed by verbatim transcription and via field notes, memos, and visual products. The interviews are analyzed using qualitative content analysis [8, 12, 13, 24, 25].

FGs. The number of participants in the focus group sessions varies greatly, from three to 30. FGs are conducted both in person and online as interactive e-meetings (via platforms like Skype or Meets), with in-person meetings usually having fewer participants (from three to five). The number of meetings varies between two and 15, depending on the research needs. These activities typically last between 2 and three hours. Documentation is collected through audio recordings which are then transcribed anonymously, and also via field notes, meeting agendas, and visual products. Information analysis generally involves reviewing and summarizing key aspects [12, 13, 24, 25, 26, 27, 28]. Some studies use qualitative analysis software for transcription and data analysis, such as NVivo 12 [8].

Persona Method. The number of defined archetypal profiles varies according to the context and research needs. In the analyzed publications, five different profiles are used on average. The patient-based archetypes usually include data related to the following aspects: sociodemographics, personal interests, partnership situations, common attitudes and behaviors related to health, and other information depending on the specific interests of the study [24].

All these different methods are often used together in a single project to establish touchpoints [12]. Co-design activities are usually planned and structured by the researchers carrying out the study [27]. In addition to these user-centered methodologies, the first phase of studies includes complementary activities such as literature review and analysis [15]. Although this paper does not focus on the methods used in the phases after the initial analysis of the needs of the users, we have considered it relevant to include a summary of the more popular methods, especially considering that there is an important emphasis on the development phase in the reviewed works. After the initial analysis phase and before the main development phase of the project starts, it is common to prioritize the identified needs. For this purpose, tools such as the Delphi method, a dynamic system that aims to reach the consensus of a group of experts on a particular topic, are used [28]. In the following phase, the development of the proposed improvement strategy is carried out through the creation of different prototypes that allow for an iterative and joint optimization process. In this phase, it is usual to hold sessions, creative workshops or focus groups, and to stimulate brainstorming and a dynamic of debate and exchange of ideas. These activities are always adapted to the characteristics and needs of the group, as well as to the research goals [3, 8, 12, 13]. After the development phase, usability testing of the tool or strategy (for example, heuristic evaluation with experts) and user satisfaction questionnaires are carried out to evaluate the results [9, 30].

Case studies. As a case study, previous works have conducted a review to establish the requirements that users of digital health services have through research projects that include co-design processes in healthcare, with a focus on people-centered methodologies [3]. A different case study made use of the HCD methodology to assess the post-participation perspective of nurses and patients in rural Tanzania [13]. Another study used co-design methods to develop a goal-setting tool shared with parents in speech and language therapy [27].

The discussed methodologies have also been applied in the design of eHealth (digital health interventions) [8] and mHealth (telemedicine that uses mobile devices) [15]: for colorectal cancer survivors and caregivers [8], to digitize patient preferences in palliative care through a mobile application [30], for integrated healthcare services for people with disabilities, caregivers and health professionals and improve digital health equity [9], a two-way messaging app for low-income and chronically ill patients [23], an app to reduce the psychosocial impact of human papillomavirus testing [24], etc. We have also identified two case studies that aim to improve patient care and information transfer between health professionals [25, 26].

In summary, the application of design methodologies is more frequently used in the digital health domain, although there are frameworks that also integrate some of these methods for their use in the healthcare sector.

3.2 Specific Search: Which design methods have been applied in the optimization of antibiotic prescription?

In this subsection, we discuss all the methods retrieved through the *specific search* and include case studies where these design methods have been applied in the context of optimizing antibiotic prescribing.

General description of the methods used. The reviewed research works in the context of antibiotic prescription use the following methods: field observations, interviews, and FGs [17, 20]. The profiles of participants collaborating in this research include antibiotic-prescribing clinicians (both residents and attending physicians, with the presence of physicians specializing in infectious diseases), pharmacists, and nursing staff. The recruitment of these specialists is carried out with the support of the medical management of the healthcare centers involved in the research, who help to find physicians interested in participating. Contact is also made through email and face-to-face communication [17, 20, 31].

Field observations. This method has only been used in one of the eight analyzed studies. Field observations were carried out under ethnographic and anthropologic research concepts through the morning and afternoon shifts to observe changes in workflow during 24 hours. The observed data were transcribed and presented graphically [20].

Interviews. The reviewed works carried out non-structured interviews, conducted by the design engineers participating in the studies. Physicians, nurses, and pharmacists were interviewed. The number of interviews (with eleven participants) is only reported in one of the eight analyzed studies. The observed data were transcribed and presented graphically [17, 20].

FGs. Focus groups were formed by multidisciplinary panels, consisting of prescribing physicians, specialists in infectious diseases, pharmacists, nurses, design engineers specialized in ethnographic techniques and computer engineers. An open-ended question guide was used for the FGs. The reviewed research works carried out

between two and three FGs [17, 18, 20]. The data were registered via detailed notes and audio recordings, which were later transcribed literally. Participants were rewarded with a gift card for their participation. The duration of FGs was one hour [31].

Case studies. Two types of tools can be distinguished in the analyzed publications: (1) repositories with information and recommendations on the use of antibiotics and (2) prototypes of antibiotic prescription assistance systems. The main goal of the investigations of both typologies is to perform usability tests and evaluate the proposed digital solutions.

Regarding the repositories, we have identified a study which presents a digital app (*Antibiogram+*) which collects information on antibiotic susceptibility, antibiotic selection, treatment duration, dosing and monitoring of antimicrobials. It is accessible through the hospital's electronic medical record and intranet [32]. A different study has developed a web interface that displays antibiotic recommendations and their properties, aiming to train physicians on clinical practice guidelines (CPG) regarding antibiotic treatment [33].

Regarding prototypes, a study analyzed the usability and functionality of a decision support assistant for antibiotic treatment in pediatric infections [34]. Another study aims to translate user needs into technical computing requirements by analyzing the usability of a commercial system of decision-making processes in the context of antibiotic treatment [31]. A tool that acts as a digital antibiogram (*iBiogram*) has been identified in the state of the art. This tool uses patient macro data, resistance patterns, and expected antibiotic coverage to help clinicians select the best antibiotic therapy without susceptibility data, i.e. when microbiological data is not yet available [35]. The research that comes closest to our goal makes use of user-centered design methods to establish the requirements of the antibiotic decision support system for an intensive care unit [20].

The presented case studies, which focus on the optimization of antibiotics prescription, use design methods which are associated with the prototyping and evaluation phases of already designed solutions with a focus on iterative improvement. Focus groups appear to be the predominant method in the literature. However, none of the interventions studies the design of the antibiogram as a strategy, and only one of the analyzed works takes into account these methods in the early phases of analysis. [31]

4 Discussion

The UCD methodologies applied in the context of healthcare (FGs, interviews, field observations, and Persona method) do not show a standardized practice; they are flexible tools that researchers can adapt to different types of studies depending on their research requirements. This flexibility also entails a clear disadvantage, since not having standard application basics hinders the usability of these methodologies to

non-design-specialized researchers. Although the number and recruitment process for participants, the different media and data registration methods are usually registered and described in the literature, there are important details that are not discussed, like the structural and organizational level of interviews, FGs or field observations. Other works do not report on the methodological script either, adding subjective variables for non-experts and increasing the complexity of reproducing existing methodologies. Additionally, the procedure used to analyze qualitative data is often not discussed either. This lack of standardization evidences the need for transversal analysis like the one presented in this project, which can facilitate non-experts using these methods in a guided and structured way. Regarding the user-centered approach in the development of tools for decision-making assistance of antibiotics: UCD methodologies allow for an in-depth knowledge of all the aspects that come into play at the time of prescription, based on a global vision of this clinical practice. This is a clear advantage for prescribing physicians and patients alike.

Limitations and future work: The analyzed sample size (N=28), search keywords and other filters applied to the review are important factors of the analyzed results, since some important related research might have been excluded (for example, if the keywords are not well aligned). In the future, other keywords like *Design Thinking* or *Codesign* could be included for a more extensive review. As a necessary research framework based on the conclusions of the present study, it would be interesting to design a guide based on user-centered methods for the initial phase to specify, detail and standardize the procedures for their application in health. In the specific case of the antibiogram optimization project through the application of design methodologies, it will be carried out: field observations, expert interviews and observation sessions based on eye tracking technology to know how prescribing doctors consult the antibiogram and co-creation sessions, focus groups, prototyping and testing of the tool in the design and development phases, ensuring the application of UCD throughout the process.

5 Conclusion

The goal of this publication is to carry out a critical and descriptive analysis of how user-centered design methodologies (UCD) are implemented in healthcare settings. The analysis focuses on the methods used during the initial phase of project development, primarily aimed at identifying and addressing the needs of end-users. This review maps validated methods, recognized by the scientific community, that facilitate the design and development of projects utilizing human-centered design methodologies. These methods form the basis for a forthcoming case study by the authors on optimization of antibiotherapy through improved antibiogram design.

In practice, UCD methods in healthcare are qualitative and descriptive, utilizing co-design tools such as focus groups and interviews, with field observations and the Persona Method also being widely employed. Co-design is present in all the reviewed articles with the participation of interdisciplinary profiles: healthcare professionals (attending physicians, resident physicians, nurses, pharmacists), patients, caregivers,

and engineers with expertise in design and ethnographic techniques. Participant recruitment often occurs onsite at healthcare facilities through direct interaction or with assistance from medical management, and communication throughout the project usually involves face-to-face interactions, emails, calls, or messages. Informed consent is typically documented in writing, though verbal consent is also common.

The methods are prioritized as follows: (1) Focus groups (FGs) are the most prevalent, conducted both in-person and remotely, though there is significant variability in the number of sessions, their structure, and participant count, usually lasting one to three hours; (2) Interviews, with the number per study ranging from 10 and 30, typically lasting 30 to 40 minutes; (3) Field observations, which may be non-participative or participative, with varying time allocations based on the study's needs; (4) the Persona method, generally creating around five profiles. Data from these methods are often collected via voice recording and transcribed verbatim, supplemented by field notes and visual documentation. However, the analysis process for qualitative data is not extensively detailed.

The research reviewed largely focuses on applying these design methods during the intervention development and validation phases. There is a noticeable lack of detailed descriptions of design tools for initial user needs analysis, which is often supplemented by a literature review. Typically, two to three of the described methods are used in combination within the same study, demonstrating that these methods are complementary and essential for yielding robust and validated findings. Most case studies apply these methodologies to the development of digital platforms, such as informational repositories or assistive technologies, although their application in developing clinical decision-support tools remains limited.

In conclusion, our study compiles a range of user-centered methods that contribute to humanising healthcare by promoting the development of projects that address the comprehensive needs of patients, clinical staff, and all other stakeholders involved.

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