Visualizing the Invisible: A Human-Centric Barrier Layer for Healthcare Systems Requirements Modeling

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***Abstract*—Information systems (IS) are fundamental to supporting healthcare delivery. Yet, human barriers hindering system adoption (in healthcare and in general) remain largely overlooked during requirements specification, leading to systematic failures in adoption and integration. This challenge is increasingly critical as healthcare transitions toward home-hospitalization and person-centered care (PCC) models. Moreover, while current healthcare IS research primarily focuses on clinicians and patients, the role of informal caregivers is rising, necessitating systems that specifically address their unique needs and barriers. This research in progress proposes a novel Barrier Layer visual notation, grounded in the Physics of Notations (PoN), to identify, specify, and communicate human-centric adoption barriers early in the requirements engineering (RE) process. Based on a literature review, thirteen barrier categories were identified and mapped to a corresponding set of visual icons. Preliminary results, including two rounds of notation evaluation with experts (N=17) and novices (N=40), and a Design Thinking (DT) workshop with caregivers and clinicians within a case study of a Neonatal Intensive Care Unit (NICU), demonstrate the feasibility, utility, and capability of the notation to help prevent system adoption failures from inception.**

***Keywords*—Human barriers, Healthcare, Caregivers, Physics of Notations, Visualization, Design Thinking, Model-Driven Requirements Engineering.**

I. Introduction

In an era when digital information is readily accessible from the palm of one's hand, human-related barriers continue to hinder the adoption and effective use of IS, particularly within the healthcare domain [1]. This becomes especially apparent for individuals requiring ongoing medical treatment, whether at home, in hospitals, or in care facilities. A significant and growing portion of care is shifting toward the home environment, where treatment is primarily administered by patients' informal caregivers i.e., family members, adult children, or close relatives [2, 3].

Despite their pivotal role, caregivers remain a largely overlooked stakeholder group in healthcare IS research, which has traditionally concentrated on clinicians and patients [4]. Caregivers face significant operational and emotional challenges: they must incorporate complex healthcare-related tasks into existing daily routines, including transporting patients to appointments, ensuring medications are taken on time, managing follow-up care, accessing and interpreting health information, scheduling treatments, and providing continuous emotional support [5]. Research indicates that caregivers tend to visit physicians more often, use more medications, and experience higher incidence of health problems compared to non-caregivers [6]. While digital systems could ease this burden, they must first overcome the human barriers that prevent effective adoption and sustained use. While traditional RE modeling languages excel at capturing functional and organizational structures, they lack mechanisms to systematically formalize the latent human-centric and cognitive barriers of users [7, 8].

Failing to identify and address these barriers leads to systems that do not meet user needs, resulting in high abandonment rates, operational inefficiencies, and systematic failures in system integration. However, current RE processes, while generally addressing various requirements related to these categories, lack structured methods to formally specify and communicate the respective potential barriers early in the system development lifecycle.

This research aims to address this gap by proposing a *Barrier Layer*: a visual notation for representing human-centric adoption barriers within standard RE diagrams (e.g., UML Use Case). The notation is grounded in Moody's Physics of Notations (PoN) [10], which provides nine principles for designing cognitively effective visual languages. The notation is developed and validated in the context of healthcare, for the case of informal caregivers of patients, through iterative evaluation cycles and real-world case studies in diverse settings, following the Design Science Research (DSR) framework [7].

The rest of this paper is organized as follows: Section 2 provides the theoretical background about human barriers to IS adoption, principles for effective visual notations, and the role of informal caregivers. Section 3 presents the goals and questions guiding this research in progress. Section 4 presents the research method and Section 5 the preliminary results obtained so far. Section 6 summarizes the contribution expected from the completed research.

II. Background

A. Human Barriers to IS adoption

Human barriers significantly hinder IS adoption across diverse healthcare contexts. Studies focusing on specific patient populations, like older adults with dementia [16], patients with Alzheimer's disease [16], and individuals undergoing home-based cancer treatment [12], consistently identify barriers related to perceived complexity, limited digital literacy, and insufficient human interaction.

Research conducted across population subgroups further reveals distinct barrier profiles: studies on individuals from low socio-economic positions highlight intrapersonal barriers such as distrust and lack of time, interpersonal barriers including insufficient training, and ecological barriers such as limited internet access [13]; studies on populations in developing countries identify system-centric barriers (network infrastructure, device availability) alongside patient-centric factors (cultural norms, poverty) [14, 15], and research on religiously and ethnically diverse populations surfaces cultural barriers that vary significantly across communities [13,14]. A complementary strand of research synthesizes these findings into taxonomic frameworks, grouping barriers along axes such as People, Hardware, Software, Data, Network, and Procedure [1], or personal, environmental, technological, and chronic disease-related factors [9]. Both highlight that even ostensibly technical barrier categories carry a strong human dimension.

While recognizing these types of barriers hindering IS adoption and therefore the benefits it aims to provide, the systematic anticipation and consideration of these barriers in the early stages of IS development remains an open challenge. An effective visual notation, enabling the representation of and communication about human barriers, is an important facilitator of such systematic approach.

B. Principles for Effective Visual Notations

Visual notations are a primary interface through which RE practitioners communicate conceptual models to diverse stakeholders [8]. As such, these notations need to be easy to use and understand. Cognitive fit theory [18] establishes that the effectiveness of a visual representation depends on the match between the representation and the task. Modeling tools must align with users' cognition to function as effective cognitive artifacts that support reasoning for the task at hand, rather than interrupt it [19].

An acceptable framework for the cognitive effectiveness of visual notations is the Physics of Notations (PoN). It provides nine guiding principles for designing cognitively effective notations: semiotic clarity, perceptual discriminability, semantic transparency, complexity management, cognitive integration, visual expressiveness, dual coding, graphic economy, and cognitive fit [10]. Despite the widespread citation of the PoN, most notation designers do not fully adhere to all nine principles and, critically, do not validate their designs with end users [8, 20]. The proposed research explicitly aims to follow all nine PoN principles, including a systematic iterative validation with relevant user populations.

C. The Role of Informal Caregivers

Caregivers constitute a critical, yet underrepresented, stakeholder group. Family informatics research demonstrates that sharing health knowledge within families leads to better care decisions and outcomes [2], and that family caregivers play central roles in hospital-to-home transitions, ongoing patient monitoring, and rehabilitation [21].

Studies on home-based cancer care, dementia, and post-cardiac surgery indicate that caregivers actively seek digital tools tailored to their needs, yet current systems rarely account for their specific barriers [3, 5]. For example, parental involvement is especially critical in Neonatal Intensive Care Unit (NICU) settings, where pre-term birth places parents under considerable psychological strain including elevated anxiety, depression, helplessness, and a diminished sense of parental role [22]. Secondary traumatic stress, arising from exposure to a loved one's suffering, further reduces caregiver availability and effectiveness [23].

Approximately one-third of caregivers suffer from clinical depression, anxiety, severe burden, burnout, or chronic stress, compared to the general population, where clinical depression and anxiety affect only about 4.4–5% of individuals [24]. This further highlights the dire need of support of caregiver for their own well-being as well as the continuity and success of patient treatment. Therefore, designing IS that actively support caregivers rather than adding to their burden is both important and urgent [24].

While existing RE approaches address various system aspects, there is no structured method to systematically formalize and visualize latent human-centric adoption barriers directly within standard behavioral models.

III. Research Goals and Questions

The proposed research aims to develop a Barrier Layer in the RE process: a new methodology enabling requirements engineers to proactively identify, visualize, and communicate human-centric adoption barriers early in the software development lifecycle, and to translate these barriers into actionable, barrier-mitigating system requirements. To ground the development of the visual notation for the Barrier Layer in real life, we perform the research using concrete use cases in the healthcare context, where the literature indicates substantial barriers of technology adoption. Informal caregivers face a unique intersection of barriers distinct from patients or clinicians: they lack formal medical training, endure secondary trauma, and navigate complex indirect data access and liability issues [5, 23]. Therefore, we ground the notation on informal caregivers with diverse conditions as the primary research population, providing rich and challenging test cases across multiple caregiving contexts.

The research is guided by the following questions:

RQ1: How can we identify and specify human-related barriers to adoption and use of healthcare IS?

- RQ1.1: What specific barriers have been reported in the literature of healthcare IS?
- RQ1.2: How can such barriers be elicited?
- RQ1.3: How can we visually represent the barriers during the requirement phase?

RQ2: How can we specify requirements that will effectively address the identified barriers?

We will pursue addressing these questions grounded in the case study of informal caregiver.

IV. METHODS

The research is framed within the Design Science Research (DSR) framework [7], cycling between the Rigor Cycle (grounding in the knowledge base), the Design Cycle (iterative artifact creation and refinement), and the Relevance Cycle (real-world validation with practitioners).

We performed a literature review for identifying and synthesizing barriers to healthcare IS adoption across multiple review studies. Barriers were extracted, listed, and grouped into emergent categories adhering to the PoN principle of semiotic clarity [8], ensuring each barrier mapped to exactly one category, a prerequisite for unambiguous visual representation. Real-world scenarios may trigger intersecting barriers (e.g., Data and Privacy), which are represented using multiple distinct icons.

A visual icon was designed for each barrier category in collaboration with an expert graphic designer. The design process was guided by all nine PoN principles [10], with a dual-color scheme ensuring perceptual discriminability for color-blind users and black-and-white printing. Notation validity is assessed iteratively via surveys using a five-point Likert scale [17] as well as qualitative feedback from open-ended survey questions with RE engineers as domain experts and IS students as novice users. Icons are intended for direct incorporation into UML Use Case diagrams and other standard RE models, placed on the association links between actor and use case to mark barrier-affected interactions [26].

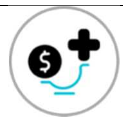
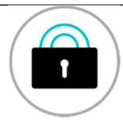
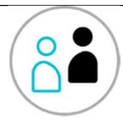
Case studies are conducted with informal caregivers across multiple hospital departments and community healthcare providers. Aiming to include highly diverse population, the case studies engage participants from multiple religious groups, socio-economic backgrounds, urban and rural environments, and wide variation in technological familiarity, which is expected to reveal a broad and representative range of barriers [13,14]. Helsinki Committee ethical approval is obtained for all human subjects' research activities prior to data collection.

For each case study, at least one of the following methods was employed: Design thinking (DT) workshops, semi-structured interviews, or structured questionnaires simulating the DT workshop flow. DT is employed to ensure solutions align with stakeholder desirability and operational viability [27]. Since patient care requires close collaboration between healthcare staff and family caregivers, both populations are included in all workshops. The iterative DT process comprising persona definition, empathy mapping, problem statement, ideation, prototyping, and testing, enables barrier-aware requirements elicitation from both caregiver and clinician perspectives simultaneously. In the next section, we report on the results obtained so far, including the barrier categories synthesized from the literature review, and the first iteration of visualization design and evaluation, including surveys and a case study.

V. PRELIMINARY RESULTS

Synthesizing barriers from multiple systematic literature reviews [1, 9, 13, 14] yielded 13 barrier categories. The barrier categories are presented in Table 1. Each category adheres to semiotic clarity with a strict one-to-one mapping between barrier and category [10]. A corresponding icon was designed for each barrier category, with a dual-color scheme employed throughout to ensure visual discriminability.

TABLE I. BARRIERS ICONS

Barrier Category	Icon	Rationale
Benefit Cost Ratio		The scales visually represent the mental process of weighing benefits (plus) against cost (dollars) to determine value
Technological Savviness		A person facing a screen with a question mark symbolizes the confusion or uncertainty users feel when interacting with unfamiliar technology
Cost		The coin and pocket represent "out-of-pocket" expenses, illustrating the direct financial burden on the individual user
Hardware		A router and antenna are used as a universal symbol for physical connectivity and the infrastructure required to access the system
Software		The circular arrow (update/sync symbol) represents the continuous cycle of software maintenance, updates, and compatibility requirements
Personalization		The ID card with a person's silhouette illustrates the system's ability to recognize and adapt to the user's unique identity and preferences
Data		The cylinder is the standard technical metaphor for data storage, representing the integration of data from the different systems
Privacy		The shield and padlock combine symbols of protection and restriction, representing the "locking" of personal information from unauthorized eyes
Human Interaction		Two figures in conversation emphasize the human element that some users prefer over a purely digital, automated experience
Time		The clock is a direct representation of the time investment and duration needed for learning or using the system
Awareness		A file within a folder symbolizes the organization of information; a barrier here represents the "hidden" or unknown existence of the system
Liability		The shield symbolizes the defensive measures and legal protections required to manage risks and potential legal claims associated with system use
Cultural		An ancient monument represents long-standing traditions and societal norms that may resist or conflict with modern digital change

An initial pilot survey [28] with 17 RE engineers confirmed high semiotic clarity (mean 4.6/5) and visual expressiveness (4.5/5) but revealed relative weaknesses in semantic transparency (3.2/5), complexity management (3.0/5), and dual coding (2.7/5) [28].

Qualitative feedback from the open-ended responses revealed that several icons, specifically Hardware and Software, were not intuitively understood without their accompanying labels. E.g., "The Software icon does not suggest its meaning". The category Awareness was similarly noted as unclear and unrelated, when referring to a given system. This feedback led us to change their design as follows: we integrated Awareness into Personalization, referring only to awareness of functionalities within the system, renamed Software to Maintenance, and redesigned the icons of Hardware, Maintenance, and Personalization, as shown in Table II.

A follow-up survey with 40 IS undergraduate students demonstrated substantial improvement in all targeted principles: semantic transparency rose from 3.2 to 4.3, complexity management from 3.0 to 3.8, and dual coding from 2.7 to 4.1 [28]. Importantly, while the two populations differ, the most pronounced improvements occurred specifically for the three redesigned icons, providing targeted evidence of the iterative refinement process effectiveness. A larger-scale validation study including both populations is planned as part of the ongoing research.

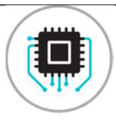
A pilot DT workshop was conducted at the NICU of a public hospital, with the participation of three clinicians and four parents of premature infants hospitalized in the unit within the preceding two years. Participants completed persona definition and empathy mapping exercises, then co-designed solutions for the identified barriers. The workshop identified barriers from both stakeholder perspectives, as demonstrated in the example quotes below.

Personalization (Caregivers): Information overload without clinical filtering: "There is an overload of available information. We need to find the relevant data that is balanced, providing enough detail to prevent complacency without causing unnecessary stress."

Data (Caregivers): Insufficient real-time monitoring: "While the baby is still in the unit, we cannot see the updated medical records from home and need to communicate via WhatsApp or phone."

Liability (Clinicians): Concerns about online advice contradicting colleagues: "When sharing an opinion online, we might contradict the opinion of another physician".

TABLE II. BARRIERS ICONS

Barrier Category	Icon	Rationale
Hardware		The CPU and cables represent the physical infrastructure and connectivity required to access the system
Maintenance		Web browser window represents the software environment, while the cogwheel represents the underlying support mechanisms needed
Personalization		The interface displays a mirrored user avatar, symbolizing a system that reflects the user's identity and specific requirements

Time (Clinicians): Insufficient capacity for real-time digital updates within existing workflows. E.g., "The medical staff lacks the time for real-time updates on the infant's status in the NICU or responding to parental inquiries via the application."

These barriers were modeled using the proposed notation on UML Use Case diagrams, placed on the association links between actors and use cases as shown in Fig. 1. The resulting diagrams demonstrate the Barrier Layer, which enables a clear visual communication of multi-stakeholder constraints within a single model. Importantly, addressing the caregiver Data barrier (real-time access) introduced new clinician barriers (Data consolidation across systems; Privacy concerns due to external data exposure), demonstrating the notation's utility in surfacing requirement interdependencies that would otherwise remain invisible until late in development. Clinicians and parents developed mutual understanding of each other's constraints and actively co-designed barrier-mitigating requirements, a finding that strongly validates the multi-stakeholder DT methodology.

VI. Discussion and Next Steps

The preliminary results demonstrate the feasibility and critical value of integrating human-centric barriers within RE models. The iterative evaluation of the Barrier Layer confirmed that strict adherence to PoN principles significantly improves the cognitive effectiveness of the notation. Furthermore, the NICU case study highlighted the notation's ability to uncover hidden constraints and conflicting requirements between diverse stakeholders (e.g., caregivers vs. clinicians). Moreover, while identifying barriers is fundamentally an RE task, mitigating them requires a continuous interplay between requirements specification and system design. The embedded DT process operationalizes this intersection, enabling stakeholders to collaboratively translate identified constraints into actionable design solutions.

While these initial findings are promising, they are currently limited in scale. Next steps involve conducting a larger scale validation survey with both domain experts and novices. Future evaluations will utilize task-based measures to assess how well users interpret diagrams and derive requirements, comparing our approach against ordinary textual or UML baselines. Additionally, as several healthcare providers are currently in the process of obtaining ethical approvals, future work will expand the DT workshops to diverse caregiving. The additional case studies involve the Pediatric Cardiology Department and Internal Medicine Department.

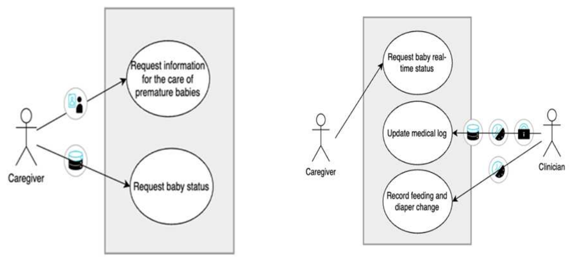


Fig. 1. UML UC example: the caregivers' use cases and respective barriers and the derived caregivers' requirement with emerging clinicians' barriers

While this paper focuses on the visualization of barriers, fully addressing the need for a systematic method to identify and mitigate these barriers by design is planned in the next steps of our ongoing research. Prioritizing the barriers and their potential solutions and resolving conflicts to ensure effective mitigation will also be considered.

VII. Expected Contribution

This paper presents ongoing research aiming to integrate human barriers into RE models. The expected contributions include: (a) A validated taxonomy of human-centric barrier categories for healthcare IS adoption, synthesized from the literature across multiple domains and refined through iterative expert and practitioner feedback. (b) A novel Barrier Layer visual notation: a cognitively effective, PoN-compliant [10] set of icons for embedding barrier specifications directly into standard RE diagrams, validated through mixed quantitative and qualitative evaluation rounds with experts and novices. (c) A barrier-driven RE methodology enabling requirements analysts to elicit, model, and communicate adoption barriers from an early phase, and to derive barrier-mitigating requirements systematically. (d) Empirical evidence from multiple case studies across diverse caregiving contexts (NICU, pediatric cardiology, home-hospitalized internal medicine, and community healthcare), demonstrating the real-world applicability and cross-domain generalizability of the Barrier Layer framework and translating these insights into a practical IS prototype designed to actively address caregivers' needs and barriers.

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