Innovative Solutions for Libraries: A User-Centric Cumulative Study on the Requirements Analysis for the Use of Social Robots

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Deployment of social robots could address the shortage of librarians in public libraries and enhance their service experience. However, this requires analyzing and reconciling the needs of customers and staff and a user-centric design approach. This paper presents a series of successive user-centered studies elucidating requirements and design recommendations for the application of social robots in public libraries. By conducting contextual inquiry via job shadowing of librarians (N = 7) and accompanying an event involving 50 librarians provided insights into their daily routines and customer interactions. Further interviews with users (N = 10) resulted in the development of personas, empathy maps, and storyboards. Artefacts were used in a final interdisciplinary workshop with researchers from human-computer interaction and business administration to create customer journey maps to model user experiences and deduce design recommendations. With that, this study provides a foundation for deploying social robots in libraries.

CCS Concepts: • **Human-centered computing** → **Participatory design**; **User centered design**; **Contextual design**; *Scenario-based design*; **Ethnographic studies**.

Additional Key Words and Phrases: human-robot interaction, social robots, participatory design, user experience, user-centered design, user research, persona, public spaces, customer journey

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1 INTRODUCTION

The role of digital technologies in public spaces is expanding rapidly, with libraries being at the forefront of this transformation. Libraries are not only repositories of knowledge but also community hubs that offer various services to

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the public. Research in human-robot interaction (HRI) highlights the potential of social robots to enhance usability and functionality of public spaces and one of its main themes explores how they can improve service experience [4, 29]. Social robots with embodied interaction affordances offer much versatility for public services, for instance by relieving short-staffed institutions and providing more opportunities for personalized interactions [67].

One of the critical challenges facing public libraries today is the shortage of professional librarians. This shortage can lead to decreased service quality and accessibility, impacting the overall user experience (UX). With the societal digitization bringing forth challenges, such as declining personnel and changes in the media landscape [39, 62], libraries are encouraged to integrate robots to improve their service delivery and UX [39, 70].

Social robots with capabilities of perception and mobility can offer both physical and cognitive assistance to library visitors, simplifying challenging activities by addressing user limitations, such as supporting the visually impaired in locating requested resources without having to rely on a library-specific categorizing system [29, 40]. By integrating artificial intelligence (AI) enabled robots, libraries can reflect on the shifting dynamics of informational, societal and economic transformation caused by the "Fourth Industrial Revolution" [47, 48, 65]. Yet, AI application in libraries remain underappreciated [48]. Hence, innovative solutions are required to support and augment the capabilities of library staff and to ensure that libraries can continue to serve their communities effectively.

The primary goal of this research is to explore the application of social robots in public libraries. This research aims to identify user-centric requirements and design considerations that can guide the successful integration of social robots into library settings. By focusing on the needs and expectations of both library staff and visitors, our study seeks to develop practical and effective solutions that enhance the overall library experience. Following a human-centered approach, it is essential to inform design decisions for social robot applications with key stakeholders' needs and requirements set in the target domain to facilitate acceptance of this technology [73].

To support the integration of social robots for public libraries, this paper presents a series of user-centered methodologies. The research process includes:

- **Contextual Inquiry**: Job shadowing of librarians and organizing a marketing event to observe interactions and gather feedback.
- **User Interviews**: Engaging with library users to understand their experiences, expectations, and concerns.
- **Development of User Research Artifacts**: Creating personas, empathy maps, and storyboards based on collected stakeholder data.
- **Interdisciplinary Workshop**: Collaboration between researchers from human-computer interaction (HCI) and business administration (BA) to develop customer journey maps (CJMs) and deduce design recommendations.

The study makes several key contributions to the field of human-robot interaction (HRI) and public applications in terms of:

- **Development of Personas**: Detailed representations of different library user groups based on observation and interview data.
- **Empathy Maps**: Edits of the emotions, needs, and pain points of individual user personas in sorted diagrams.
- **Storyboards**: Visualized narratives of use-case scenarios for social robots in libraries.
- **Customer Journey Maps**: Integration of foregoing artefacts for the comprehensive modelling of individual user experiences, highlighting critical touch-points and design implications.

By integrating these user-centered artifacts, this study provides a framework for the effective deployment of social robots in public libraries, addressing both technological and social dimensions of the integration process. Our research

yielded a wide range of antecedent requirements for social robots in libraries and associated design implications with relevance extending to other municipalities. Building on an interdisciplinary approach blending expertise in HCI and BA, we contribute practical requirements and design considerations that offer guidance for library administration and policymakers for integrating social robots to enhance the functionality and service experience in public libraries in the light of social acceptance.

2 RELATED WORK

Public libraries are an intensively studied application domain for field trialing robotic systems (e.g., [7, 25]). Supporting users' higher-order cognitive performance and addressing physical limitations in retrieving library resources [7, 46] turned attention to social service robotics [33, 40]. For instance, Behan & O'Keeffe [7] constructed a socially assistive service robot featuring autonomous mobility and social interaction capabilities to help users with physical difficulties retrieve library resources. Lin et al. [40] conducted participatory design-based research involving child patrons and librarians, resulting in a social robot prototype equipped with context-aware navigation and a human voice interface for guiding users. These studies underscore the potential of social robots to support higher-order cognitive performance and address physical limitations in library settings.

Both accounts suggest that less humanoid designs for social robots, as in anthropomorphism, still can positively influence user perceptions. However, leveraging higher levels of anthropomorphism in robot design is argued to be crucial for acceptance of robots [20], as it is assumed that individuals interact with both living and non-living entities by using human social cues [3, 29]. This premise inspired the design of more humanoid form factors for robotic systems, which commonly provide human support functions in libraries, such as reference services [69], reception of new customer [74], instructions on library service procedures and guidance [25]. Although they can handle simple information requests in a socially engaging way complemented by technological means (e.g., visualizations on display), they can only be assistants due to their lack of emotional and intellectual abilities [60]. However, as humanoid robots can serve multiple functions (e.g., Pepper [54]), human users may accept them in the role of librarians [29].

But social robot acceptance is not not only related to the functionality of the robots but also depends on how users experience the interactions [17, 80]. Additionally, HRI encourages as a interdisciplinary research field cross-disciplinary collaboration to generate more holistic solutions meeting real-world requirements [64]. Recently there has been increased interest in customer experience (CX) and its relation with UX in the HCI community, as it is proposed that their mutual dependency can be leveraged to develop high-quality interaction products [52]. Interrelating UX and CX, the latter actually describes the broadest scope of the former [59]. UX refers to user's perceptions of single interaction products, while CX includes all interactions the customer has with a company or its brand through its multiple products along the customer journey [37, 58]. CX focuses on "touch-points" in terms of moments in which the customer interacts with a brand or company, and "channels" to explain the method ("medium") of interaction (e.g., social networks). The total out of all individual touch-point experiences forms the CX emerging from the journey, which conventionally entails three distinct and interconnected stages: pre-interaction, interaction, and post-interaction [52]. In other words, UX is an obligatory component of CX and can cumulatively mature into a spectrum of interaction experiences of individual users with a social robot [56] with trickle-down-effects on the represented organisation [45].

UX research in libraries focuses on understanding and improving how users interact with library services and resources. For example, considering user requirements can lead to more effective service delivery and increased user satisfaction [43]. Libraries are encouraged to adopt adaptable, accessible, and entertaining services to engage a larger audience and improve UX [13, 69, 76]. Faster information access [48], lower human error and service costs streamline

workflows and improve on the customer experience (CX), empowering librarians to serve customers when needed [39]. However, creating high quality experiences requires systematic design and evaluation [41] and remains of significant challenge in HRI [1].

While existing research highlights the benefits of social robots for libraries, there are notable gaps that this study aims to address. First, there is limited research on user-centered design of social robots specifically catering to the needs of library staff and its users. Previous studies primarily focused on the technical capabilities of robots rather than their integration into the socio-technical system of a library. Additionally, there is need for more comprehensive studies combining fieldwork with user experience design (UXD) to capture situated needs and expectations of library stakeholders.

Moreover, the present study emphasizes the social dimension of social robot integration to facilitate acceptance among library staff and users, while the interdisciplinary collaboration between HCI and BA researchers also ensures that both its technological and economic dimension are being considered. By addressing these gaps and providing practical guidelines for the deployment of social robots in public libraries, this study contributes to the advancement of HRI and supports the transformation of public libraries into more user-friendly community hubs.

3 RESEARCH METHODS

As libraries increasingly serve as both conduits of information and community hubs, it is critical to examine user needs and the socio-technical dynamics at play within these environments. To address this, we combined field and user research with an interdisciplinary workshop. The first provided in-depth insights into the requirements and potential impacts of social robot applications on library settings, while the following workshop enabled to design for prospective user experiences holistically by building on the situated findings gained in prior. The methodological approach of the present study is illustrated as follows.

(1) **Contextual Inquiry and User Interviews** [6]: Conducted job shadowing of librarians, a marketing event, and interviews with library users in a public city library. This approach aimed at creating an extensive database of situated needs and requirements of stakeholders.
(2) **Interdisciplinary Customer Journey Workshop**: Conducted an interdisciplinary expert workshop that combined competencies from HCI and BA to map out individual customer journeys. This method facilitated the integration of diverse expertise to enhance the development of user-centered application of social robots in libraries. Additionally, the workshop studied commonalities between UX and CX perspectives to optimize the identification of essential needs of users throughout their library journey.

Following sections give an detailed overview of the applied research methodologies and procedures.

3.1 Contextual Inquiry

Studies were initiated with field research within a public city library with the goal of assessing stakeholders' needs and requirements for the deployment of social robots to inform the development of in-depth design artifacts. Throughout these activities, we closely collaborated with library management, who were interested in learning about the prospect how AI enabled autonomously learning robots may support library operations in the future.

Visiting the target domain on two different occasions at different hours of the day, at specific locations for "needfinding" [49, 72], allowed us to experience the environment, empathize with visitors and employees by documenting their

feedback, observe, and immerse in the status quo to reliable assess user needs and requirements in its natural social context.

3.1.1 Job Shadowing - Procedure. Over one day seven employees were accompanied by one researcher to capture their daily routines, interactions with library visitors, and related challenges. Library premises and dedicated functions were inspected and interactions with customers were recorded to identify frequently asked questions and problems. Shadowing employees is relevant as they have in-depth experience in dealing with customers [72].

3.1.2 Marketing Event - Procedure. A marketing event was organized and held by the researchers at the same library where the shadowing occurred to deepen the participatory involvement of employees. Three different showcases were employed by the researchers. First, in a virtual reality (VR) environment participants could interact with the humanoid social robot Pepper in a library setting. Second, the functional service robot system Temi demonstrated functions of way-finding, telepresence, tracking and interface options. Third, the functional delivery robot Pudu introduced as "Ro-Bin" was presented. "Ro-Bin" simulated the return of board games via a predetermined dialog with voice output and identified games with an additionally installed container by weighing items. The VR showcase did not support interaction with the other robots presented at the event. Employees and visitors were encouraged to leave feedback on pin-boards and discuss the use of social robots in libraries.

3.1.3 User Interviews - Sample, Methods and Procedure. Library users (N = 10) were interviewed in a public library to gain an in-depth understanding of their experiences, expectations, and concerns regarding the use of social robots in libraries. Participants were recruited via calls for study on social media channels of local libraries and word of mouth. All participants were briefed and provided informed consent prior inquiry. A semi-structured interview guideline based on three main categories was employed. First, participants were asked to outline their daily routines, assess their openness for technology and how long they have been using the library. Second, participants' emotions, experiences and wishes related to library services were queried. Third, participants' social acceptance towards, expectations on, and what they imagine the useful and inclusive application of social robots in libraries to look like were probed for. Finally, demographic variables were collected via questionnaire. Interviews took about 20 minutes to complete and each participant was reimbursed with 20 Euros. Interviews were audio recorded, transcribed and a coding scheme was developed employing deductive and inductive qualitative content analysis [44]. Participants included one male, eight females, and one diverse individual, aged between 18 and 80, reporting predominantly higher education levels. We additionally assessed affinity for technology, as in handling of and attitude towards electronic devices in general with the TA-EG questionnaire [31]. Sub-scales show participants are rather moderately excited (M = 2.6, SD = 0.99), but feel competent in use (M = 3.44, SD = 0.9) and hold a more positive (M = 3.7, SD = 0.48) than negative attitude (M = 3.2, SD = 0.4) towards consequences of using technological devices.

Combination of field findings with interview results yielded an extensive database about user needs, activities, goals, emotions and antecedent requirements on the application of social robots in public libraries.

3.1.4 Creating User Research Artefacts. Data collected from the field and interviews were used to design UX artefacts, such as affinity diagrams, personas, empathy maps and storyboards. This process aimed at synthesizing insights into actionable formats that can guide the design of deployment strategies for social robots in libraries. The artefacts were used to inform the collaborative compilation of CJMs within an interdisciplinary expert workshop. Examples of personas, empathy maps and storyboards are provided in the appendix and the complete materials can be found in the supplementary materials.

(1) **Affinity Diagrams**. In preparation, field data was categorized and labeled using affinity diagrams to extract user needs and edit relevant data points in a structured manner. This allows to identify relevant topics and creates an accessible overview of users' attitudes, needs, challenges and touch-points [8].
(2) **Personas & Empathy-Maps**. Based on collected user data, four personas were created to represent a diverse group of library users. These personas include detailed context data relating to library use, personal attitudes towards technology and social robots, and accompanying emotions and challenges. Data points allow to reflect on library user's goals and behaviour. The personas and dedicated empathy maps purpose is to provide a sophisticated image of potential users to help guide the design of social robot applications towards positive UX [51, 57] (see Appendix, Fig.2 and Fig.3 for reference).
(3) **Storyboards**. Analysis of user data supported the creation of storyboards to visualize use-case scenarios intended to serve as a basis for the modelling of prospective user experiences in form of CJMs. Storyboards were designed based on one of the previously created personas considering their unique needs and expected challenges [11]. Storyboards not only included the momentary interaction between user and robot, but provided a holistic frame of reference for the entire user journey, including touch points before a social robot is even encountered in the library for the first time (see Appendix, Fig.4 for reference).
(4) **Customer Journey Map**. The customer journey map visualizes the customer or user experience including users' needs, goals and emotions, often based on personas informed by user research. This enables the mapping of touch- and pain points, detailing the steps users take, their objectives, and how their emotional state interrelate with these elements throughout different stages of the journey [23].

3.2 Interdisciplinary Customer Journey Workshop - Sample, Methods and Procedure

An interdisciplinary workshop was conducted with four researchers from (HCI) and two from (BA) to develop CJMs and deduce design recommendations. The workshop was moderated by a researcher and held online over a video call. A collaborative whiteboard platform was used to present materials and capture participants' mapping inputs. First, the moderating researcher gave an introduction in materials to establish common ground about the journey and its mapping. Each map was to comprehensively model the UX of one persona in reference to its corresponding use-case as depicted in the storyboard. The workshop alternated between mapping and discussion phases. With four mapping templates prepared and each mapping phase entailing two interdisciplinary subgroups, two cycles were run in total. Mapping occurred in break out sessions supported by user research artifacts, guiding questions and instructions. During mapping, participants were encouraged to adapt the mapping procedure to align both perspectives of user and customer needs respectively. After each mapping run, subgroups converged for presentation and general discussion of mapping results.

Mapping templates predetermined the phase structure, which was designed to facilitate interdisciplinary journey mapping. Included mapping dimensions were persona's steps, goals/needs, touch- and pain points with the library or robot, emotions and suggestions for improvements. Mapping inputs for all dimensions with exception of emotional state were collected via post-its. Emotional perception was plotted as a continuous line throughout the phases highlighting emotional "highs" and "lows" of the experience. Additionally, each step can be associated with an discrete emotion portrayed by an emoticon (e.g., frustrated, happy). Each template was supplemented with a persona, a corresponding empathy map and a storyboard to inform the mapping process. Personas are considered to be an essential foundation for journey mapping procedures, as they consolidate much of the required information in one user artifact [23]. Empathy

maps were attached to facilitate relating the information in the mapping dimensions to the emotional state along the journey. Main units of journey analysis were mapping dimensions.

Next section presents the results of the stakeholder research arranged in the contextual inquiry, qualitative data analyses of user interviews and the expert workshop. Results provide insights into the needs, requirements and expectations of library users and staff, and the relevant design considerations this informs to deliver on high quality UX with social robots in public libraries. A foundation is laid for discussing the implications and social robots' application potential for public libraries, contributing to HRI in public spaces.

4 RESULTS

4.1 Job Shadowing

Job shadowing revealed several limitations in library usability and operational inefficiencies, including a lack of standards in inter-lending procedures, absence of an exhaustive information hub for current events, and no self-service options for returning certain media like board games. Common customer requests involved locating and researching media, accessing in-house resources such as copiers, and introduction to library services, particularly for new users. Employees identified potential tasks for social robots to alleviate their workload. These included allocating visitors free seats, answering FAQs, automating repetitive and laborious tasks such (e.g., renewing PC-pool accesses, shelving and transporting media). Robots could also mediate events and perform tedious tasks with emotional impartiality as to not impair on the customers' service experience.

4.2 Marketing Event

Participants at the marketing event expressed a range of expectations and concerns. Innovative applications like escape games and accessible programming interfaces for on-site programming for robot customization were suggested. However, concerns were raised about devaluing the interpersonal contact in transferring traditional tasks of librarians to robots, and the adoption readiness of more technology-critical and older visitors. Privacy issues related to commercial AI implementations and handling insurance cases were also discussed.

Suggestions for robot tasks included assisting with physically demanding and repetitive tasks such as media transportation and handling returns, supporting navigation and resource localization, optimizing media assortment using radio frequency identifier (RFID) technology, and instructing users on library procedures leveraging multi-modal interaction techniques and multimedia. Telepresence use-cases in "open libraries" when no staff is on-site were proposed. Accessibility options such as multilingual support and consideration of physical impairments in hearing (e.g., sign language), sight (e.g, read aloud) and movement (e.g., companionship) were suggested. Using robots for unpleasant tasks for librarians, such as announcing closure and enforcing house rules (e.g., noise control) were welcomed. General requirements emphasized efficient robot navigation, streamlining the resource access, efficiency in design of natural (e.g., speech), as well as conventional means of interacting with technological artefacts (e.g., touch-pads) for when no social interaction is desired.

In summary, findings from the marketing event indicate that employees viewed social robots generally as supportive additions for the management of library operations, highlighting their potential to adapt to specific user needs more efficiently, as in supporting resource localization, reservation and return.

4.3 Interviewing Library Users

The final coding scheme contained three main (**bold**) and 15 sub-categories (*italic*). Participants stated their **personal background** (1) including *openness to new technologies*, *routines relating to library use*, *considerations for an inclusive library* and *initiation of library use*. They described their **UX with the library** (2) in terms of *what library services are frequently being used*, *associated emotions*, *touch-points with librarians and other patrons*, *positives of library use*, *barriers of library use* and *suggestions for improving the library*. At last, the **expectations on social robots in public libraries** (3) of participants were expressed by discussing their *notion of social robots*, *worries about the use of social robots in libraries*, *requirements for social acceptance of library robots*, *desirable functions and features for social robots in libraries* and *advantages of social robots for library services*.

4.4 Workshop Results

Four unique journey maps were compiled, each one corresponding to one of the personas gained through user research. Analyzing these, we found the user journeys to be driven by motivational themes (e.g., sense of community) manifesting in user's core needs. In essence, maps reflected the journey of two user types, those who seek socially rewarding interactions and those who prefer efficient (e.g., time-saving), goal-oriented outcomes. Additional motives of seeking entertainment and testing the robot's capabilities were considered.

4.4.1 Touch Point Design and Supporting Measures. Differentiating between analogue (e.g., radio) and digital (e.g., social media) touch points was suggested to consider a target group-orientated approach. It was highlighted that even UX within a single touch point (e.g., digital platform) may act as significant influencing factor on the total experience of the user's journey. To address skeptical users' biases targeted information campaigns were suggested, that clearly communicate that social robots support staff rather than replace them. For instance, multi-channel and media campaigns distributing representative promotional material (e.g., videos, reports) in social, print and outdoor media could support the formation of valid user expectations. Additional user review outlets were proposed to share first hand experience with social robots for participatory development and foster robot acceptance.

4.4.2 Personal and Social Factors influencing the User Journey. A critical decision point in choosing on-site between librarian and robot for support was identified. It was found that environmental states and prior experiences with AI applications become pivotal for decision-making. The extent to which digital technologies are adopted in everyday life by users as an antecedent acceptance factor was suggested, as it determines not only information accessibility but also indicates technological readiness. Found various actors of the immediate surroundings may become touch points for users to reflect on their experiences. Technology-savvy people were argued as facilitators of robot use, as they might advocate for robot use and integration in society creating visibility for their benefits. Besides other visitors, librarians on-site can be central touch points who mediate and support robot use of concerned users leveraging effects of social facilitation [79].

4.4.3 Design Considerations on Public and Social HRI. Several requirements on social robot interaction design were identified. The robot must process user requests according to user expectations, act socially and contextually appropriate and be able to adapt to the changing needs of users during interaction. First use of the robot was found to be a central moment of truth, as the robot must convince users of its added value and appear intelligible. It was considered essential how the robot reacts on lay user's initial speech, for example, giving an actionable tutorial demonstrating its application purposes and means of operation. Comprehension of how to operate the robot could additionally be supported by

instructive sign-postings placed nearby. Further, the robots must be able to provide explanations about its behavior not only on the system (e.g., compilation of recommendations) but also on the socio-behavioral level (e.g. surprising gestures) according to the users' individual need for explanation that arises during interaction, so users can successfully leverage the robot's capabilities to their fullest potential.

All information should be outputted via all communication modes that the robot offers (e.g., recommendations listed on a tablet-display can be verbally presented). The robot communicates the current state of the process transparently and uses social cues to signal swift responsiveness. Users can exit the interaction at any time to preserve their need for autonomy. Employing different interaction profiles for specific groups (e.g., adults, children) or by creating personalized user profiles, including multiple language support, the robot leverages the memory of previous interactions to make more valuable and engaging recommendations for further actions. It was stressed that implementation of personalization must conform to local data protection regulations and should follow ethical principles of personal rights minimizing further negative repercussions. Additionally, the robot must be able to address the user's privacy concerns transparently.

4.4.4 Expectation Conformity for high quality HRI. There was common agreement on the theme of ensuring conformity with user expectations (ISO 9241-110 [22]) playing a central role for facilitation of positive UX and to motivate continued robot use. To uphold a continuously high interaction quality and build loyalty throughout the journey, it was considered vital to avoid any pain-points breaking the expected interaction flow (e.g., missing registration confirmation). The relevance of effective mitigation strategies was acknowledged to address occurring pain points and mitigate negative user experiences. In other words, the robot proactively tries to resolve pain-point by providing appropriate alternatives. For instance, when a requested book is unavailable, the robot presents books with related themes. Facilitating this, it was proposed to intertwine the robots' application interface with established digital touch points of the library. For instance, the robot processes book reservations made via the library app or its website enhancing user engagement and provide added value. After servicing a request, the robot could offer additional post-service options like guidance, reminders, and surveys to further sustain user engagement. For instance, when servicing customer requests that require the user's library card as a transfer medium (e.g., for event booking), this could be combined with automated follow-up e-mails to collect feedback and encourage continued use. Straightforward and lightweight feedback surveys could give insight into how to improve the UX with the robot and also on how to optimise the library's CX overall. All of the created CJMs are provided in the supplementary materials and an example map is given in Figure 1.

Following section discusses the study results relating them to the current state of HRI regarding social robots in public libraries. Additionally, potential approaches and strategies for future research and practice in this area are proposed.

5 DISCUSSION

We conducted extensive user-research with the goal of anticipating and designing for the prospective UX with social robots in public libraries. Holding a marketing event for employee participation revealed their notion of robot roles, status in workflows and requirements related to day-to-day operations. Contextual inquiry yielded operational knowledge, on-site experience and in-depth understanding of the social context of public libraries. It allowed us to experience the customer journey from the perspective of patrons firsthand. The participatory involvement of staff leveraged complexities of culture, technology, objectives, and politics of library operations facilitating the measurement of robots' impact. This alleviates the objectivity bias in research projects encouraging active support for robotic intervention [40]. Complementary customer interviews yielded in-depth understanding of the UX with libraries and what they require for

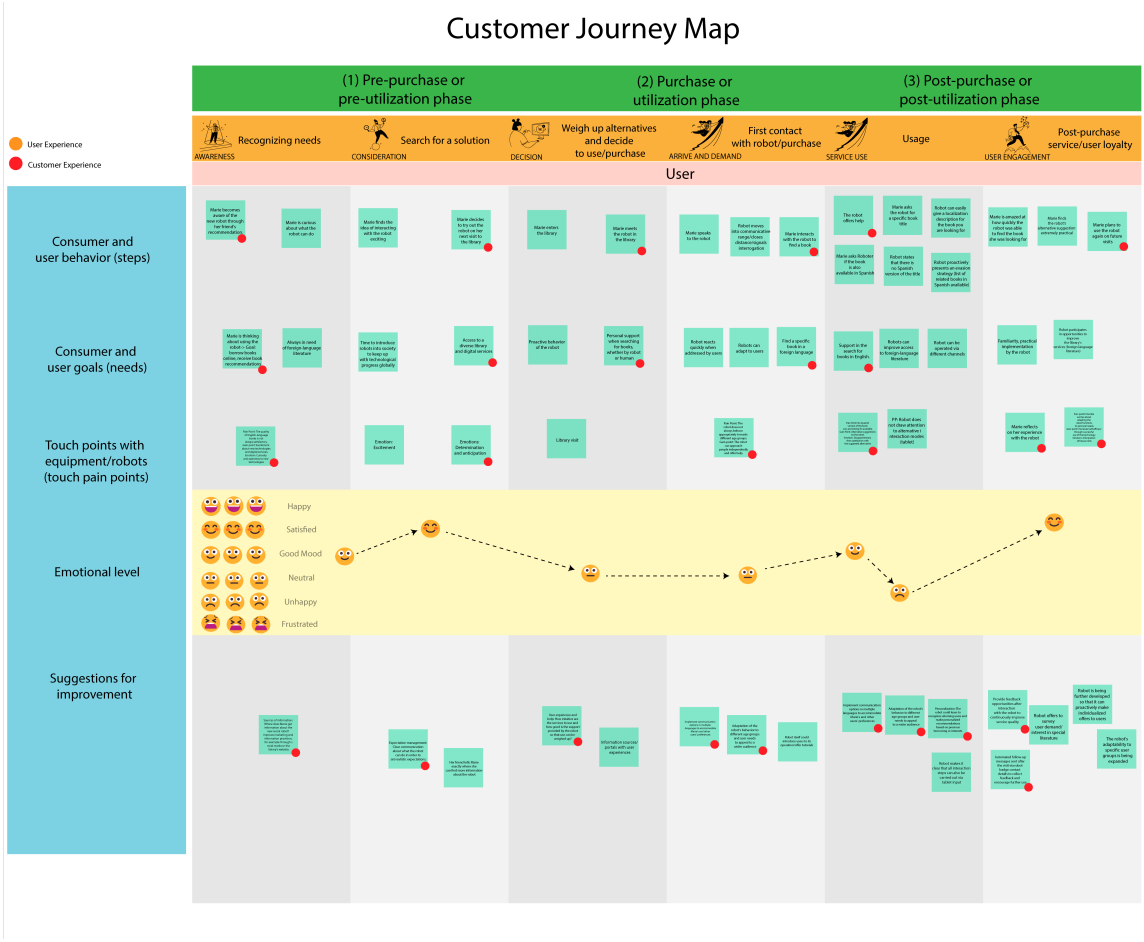

Fig. 1. Exemplary customer journey map for the "Marie" persona.

the acceptable deployment of social robots within. Taken together findings yielded substantial data about requirements and needs of both stakeholders and was used to generate empathy maps, personas and illustrative storyboards to support an interdisciplinary workshop for the customer journey mapping between HCI and BA researchers. Final outcome are four maps each modelling the UX of a persona with a newly introduced social robot for library services broken down in the elementary components of the CJ.

5.0.1 Insight from Contextual Inquiry. Field findings demonstrate how robots can affect libraries and its information and social environment [48] and highlight the importance of considering stakeholders' expectations on robot capabilities [39]. Our research confirmed possible applications for social robots in library environments found in prior works, such as noise control, media localization, access to in-house resources, giving instructions and answer FAQs [25, 28]. Job shadowing librarians unveiled social robots' potential for more seamless facility management (e.g., finding open seats, PC-access, library assortment), providing always up-to-date information on up-coming events and streamlining service usability (e.g., automating returns for all media). Employees deemed robots especially useful for management of library

space through automating storage and retrieval systems [21], which streamlines workflows and patrons' UX. Social robots' emotional impartiality when doing especially repetitive and tedious task was suggested to be of benefit for consistent service quality.

There is much hope that robots can make libraries more accessible and versatile in their services [48]. For instance, RFID enabled use-cases are associated with much added value for making library resources more accessible. Indeed, RFID tagged media can be used by robots to take inventory of the library's catalogue [10, 70], helping patrons to find selected media more efficiently [14]. However, due to environmental factors, such as metallic surfaces and irregular shelf configuration, RFID is not infallible [39]. For handling additional mobility challenges the library's environment may need to be modified to accommodate the robots' navigation capabilities, including removal of obstacles, reconfiguration of shelves and appropriate positioning of books. Customizability and adaptability of robots were two main themes of preliminary requirements. It was considered how robots could be utilized to unburden employees (e.g., Open Library, customer complaint management)[19, 60] and how robots should adapt to individual user needs (e.g., multilingual support, accessibility options). However, to properly handle any type of newly found condition, the robot may need to be upgraded with additional hardware components and/or software modules [39]. For instance, installation of barcode scanners on the robot may be required to support basic library services [40] and accessible programming interfaces for robots support adaption of new use-cases.

Besides the positives, concerns about loss of sociability, humanness and fear of job loss associated with integrating more robots into the service domain were raised by employees and patrons alike. Phillips [50] studied how advancements in robotics and AI affect human labor in libraries, finding automation being judged positively when used for tedious work. Present results also show that some customers were concerned that more jobs will be lost than created and that robots and AI will never be able to provide humaneness and emotion that many people consider essential in matters involving social exchange [65]. Employees' fear of being replaced appears to be correlated with the introduction of automation processes (e.g., self-checkout) [60]. But as robots are better suited for more assiduous tasks, librarians gain more opportunities to engage patrons creatively and with emotional intelligence and empathy. Fears of replacement can be also counteracted by highlighting how librarians and robots can work together to boost library performance [69] by redesigning workflows to maximize productivity [39]. Similarly, users' fear of robotic rationalization devaluing libraries connection to the community and undermining human characteristics [69] not only announces the need for upcoming mediation work, but also highlights that social acceptance of both librarians and customers is critical to reconcile. For instance, field findings support the notion that if robots appear to employees as useful coworkers that enhance their performance and professional development, adoption readiness can be increased [78].

5.0.2 Insight from Customer Journey Mapping. Customer journey mapping gave ample insight into modelling the prospective UX with social robots in public libraries. A fundamental challenge was encountered in the discussion about the contextual origin of core needs driving the journey from the very beginning (e.g., how, when and where needs arise), which was resolved by reference of touch points and personas.

The result of two basic user types found in the maps can be related to different lines of research. For once, this corresponds to modelling approaches of UX in terms of pragmatic and hedonic qualities of user-product interaction experiences [26, 27]. Users placing more emphasize on socially rewarding experiences corresponds to the fulfillment of psychological and emotional needs often linked to hedonism, while users striving for more efficient and effective results focus on pragmatism and usability in interaction experiences with socio-technological systems. Parallels can also be drawn to models of peoples' service orientation [53]. A relational orientation is characterized by a desire to maintain

good relationships even when breakdowns occur, while an utilitarian orientation strives for efficiency and correctness of the service itself. Lee et al. [34] demonstrated in accordance with the theory of regulatory fit [12], postulating that people's responses to mitigation strategies for service errors depend on their orientation, how respondents with relational orientation responded best to a robot's apology, while those with utilitarian orientation responded best to a robot offering compensation. Forewarning people to introduce the probability of breakdowns was also shown to be a effective method to mitigate negative evaluations of robots due to mistakes making it a viable strategy. This highlight the significance of robots' adaptability in matching users' preferences with appropriate behavior as a powerful tool to mitigate negative influences of interaction breakdowns and to sustain user satisfaction and trust, as breakdowns can impair on users' confidence in the robot for follow-up interactions up to abandoning it altogether [32, 55].

Such line of reasoning is also related to research showing that the degree to which a service meets people's expectations is a primary determinant of satisfaction [66]. For instance, targeted information campaigns delivered via different touch-points were proposed as powerful tools to reach specific demographics and address their concerns. As millennial's' put a greater emphasis on digital touch-points (e.g., social media), older generations prefer more analogue ones (e.g., print) [35]. Reliably informing both about social robots' capabilities and limitations helps prospective users to set adequate expectations and reflect on their attitudes (e.g., realizing that humanoid robots are not capable of substituting humans). This facilitates the formation of valid mental models preventing expectation discrepancies, which fulfills the interdisciplinary goal of establishing conformity with user expectations fostering positive UX and acceptance [42].

Adoption readiness of digital information technologies as antecedent factor for social robot acceptance corresponds to theoretical models of long-term technology adoption, where information sources are considered to make a significant impact (e.g., [18]). Consideration of UX with digital platforms as touch-points reveals that the overall user or customer experience of the journey is actually comprised of several distinct experiences made along the way [42]. Past experience at each stage of the journey may influence the current experience through expectation formation and stickiness in evaluations [36]. This mechanism was shown (e.g., [9]) to influence future usage in customer satisfaction research by which an influence on technology acceptance could also be postulated.

Social influences of the immediate surroundings as touch-points (e.g., other customers, employees) was recognized. Peers may exert significant influence in all journey stages, sometimes even surpassing the effects of advertisements [5]. The significance of tech-savvy users exerting high readiness for technology usage was noted, as this trait has been shown to be an influencing factor for robot task acceptance [2]. Tech-savviness was linked to the expectation to successfully interact with robots [38], and positively influenced perceived usefulness and ease of use of the Technology Acceptance Model [16]. This may motivate voluntary usage of robots and relate to robot enthusiasm, making tech-savvy users mediators for robot usage for sceptics setting a strong example for user acceptance [77].

Major social influences can also be mediated by digital touch-points in terms of social media [35], which combined with user reviews can offer participatory involvement for users in robot deployment to foster acceptance via co-creation. For comparison, involving visitors of a library in the development of emotional expression for Pepper demonstrated how user participation created high levels of acceptance [25].

The decision to seek on-site support of a librarian or a robot was often characterized by responding users as a question of task complexity and efficacy (e.g., time on task) and accessible resources (e.g., employee availability), expressing higher interaction readiness when staff is preoccupied and they expect the current request is easy and fast to handle with a robot. As users prior experience with established AI technologies could influence their expectations on the social

robot [42], introductory materials and nudge cues might build on these existing mental models to initiate use (e.g., getting instantaneous information on requests).

It was deemed essential to not only provide information on how to interact with the robot in global terms including creation of a basic understanding of the overall robotic logic (e.g., tutorials), but also have the robot to be able to self-explain its local behaviors on lay user requests accordingly. This helps to continuously scaffold user's comprehension of the robot's behaviour, especially to promote user confidence in the robot in first use (Sheh, 2017). Such considerations correspond to the research strain of Explainable Artificial Intelligence (XAI) that applied to social robotics is suggested to aim at creating embodied social agents that explain their behaviors to users by employing social cues describing their internal way of functioning so users can infer the respective reasons behind it Wallkötter et al. (2021) [8].

To facilitate user engagement it was suggested that the robot acts as a self-learning system to adapt its behavioral strategies to individual user's characteristics and context information [15, 68]. However, this requires development of customized user profiles modelling the user based on relevant user characteristics for the particular use case [30]. Besides the challenge of having to identify the right characteristics ethical repercussions must be considered as personalized HRI requires the disclosure of personal data that could result in potential risks for the user. For instance, loss of control can manifest when actions of an autonomous robot appear inexplicable to the user so the course and outcome of interaction can not be deliberately influenced anymore [63] opening the possibility for manipulation and paternalism [24]. This links naturally with the requirement that the interaction with the robot is consistently explainable, centers around user needs, and remains non-binding throughout, as it can be resumed at the point the interaction was previously discontinued. Similarly, privacy concerns may potentially causing users to avoid usage of personalized HRI [61]. This is detrimental as user data could be used to further the development of robots' social intelligence [75] and offer enhanced UX with future interactions [68]. Providing transparent communication of privacy policies for data processing and storage in advance could mitigate these issues [71].

Due its wide scope and conceptual approach to designing for public and social HRI, this research is subject to several limitations. Contextual Inquiry provided a cross-section of the organisation structure of public libraries and possible staff-customer interactions. Future inquiries might consider conducting job shadowing over a longer time frame to capture the specific requirements and needs of each functional area in more detail. The sample of interviewed library patrons was limited due to constrains in time and budget, but nevertheless yielded substantial input. Designing appropriate behavior mechanisms for social robots in public spaces aimed at fostering positive UX is a multifaceted challenge since the interaction between all interactive modalities like e.g. movement, gesture or voice need to be considered. Multi-user scenarios were excluded for the present design research but are likely to occur in public spaces and raise the questions of who is controlling the robot, and who has sovereignty about the data being disclosed[24]. Additionally, only a limited selection of use-cases, as in booking of events and localizing requested media, was considered for journey mapping but there are many more viable applications beyond the service domain for social robots in public libraries, for instance acting as educational reading buddies. Future research in UXD for social robots in public libraries is encouraged to extend its scope by considering new application purposes to create respective reference materials. That way, the design of high quality interactions with social robots in public spaces can be facilitated by elucidating further on relevant design recommendations and support measures and influential variables and their complex interplay.

6 CONCLUSION

This study has provided comprehensive insights into guiding the sustainable integration of social robots in public libraries, emphasizing the importance of user-centric design and understanding the specific needs and expectations of

library stakeholders. Key findings reveal operational inefficiencies in library usability and operations, such as the lack of standardized procedures and the need for accessible information hubs. Sensible use cases for robots were identified in tasks such as media localization, handling returns, providing multilingual support, and automating laborious tasks. Feedback from library staff and visitors highlighted both innovative applications and concerns. Additionally, the study developed detailed user research artifacts, such as personas, empathy maps, and storyboards, to inform the interactive design of social robots. The creation of customer journey maps further modeled the UX with social robots, identifying critical considerations on interaction design, relevant influence factors, supportive measures, as well as touch- and decision points. Present research findings offer practical guidance for library administrators and policymakers on how to implement social robots into the public domain in a meaningful manner. Integrating social robots can enhance operational efficiency, improve the service experience, and provide more personalized and accessible services. Robots can manage routine inquiries, guide visitors, and allow staff to focus on more complex tasks. They can also automate repetitive tasks such as shelving and transporting media, facilitate events, and offer personalized recommendations. Additionally, robots can support accessibility features like sign language interpretation and audio assistance. By addressing operational inefficiencies and enhancing service delivery, social robots can help libraries better meet the needs of their communities. The potential impact of social robots on the future of library services is profound. By leveraging technology to perform routine tasks and provide personalized assistance, libraries can become more efficient and user-friendly. The importance of user-centric design cannot be overstated, as it ensures that the integration of social robots aligns with the needs and expectations of both staff and visitors. As libraries evolve into modern community hubs, the thoughtful integration of social robots, informed by extensive user research and interdisciplinary collaboration, will play a crucial role in shaping their future. By continuing to explore and address the challenges and opportunities of this integration, libraries can remain vital and relevant in the digital age.

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A RESEARCH METHODS - USER RESEARCH ARTEFACTS

Following subsections give example references of the generated user research artefacts used to support the interdisciplinary workshop for the customer journey mapping.

A.1 Persona - Example

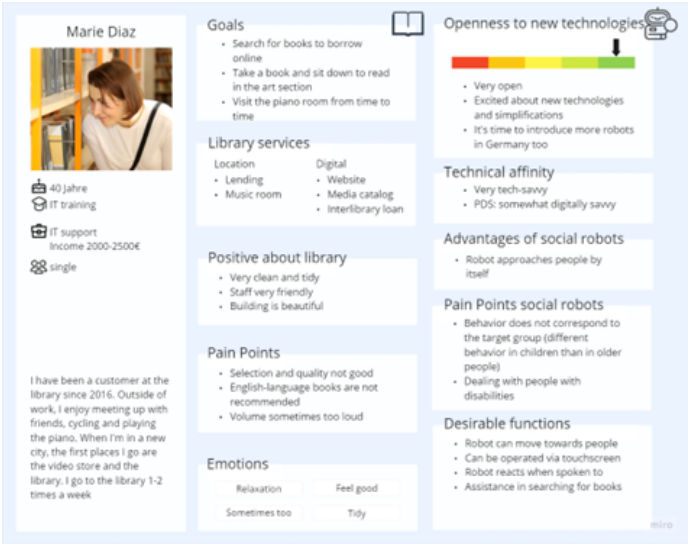

Fig. 2. Reference example of one library user persona based on user research. The "Marie" persona represents the needs and requirements of tech-savvy library users on social robots.

A.2 Empathy Map - Example

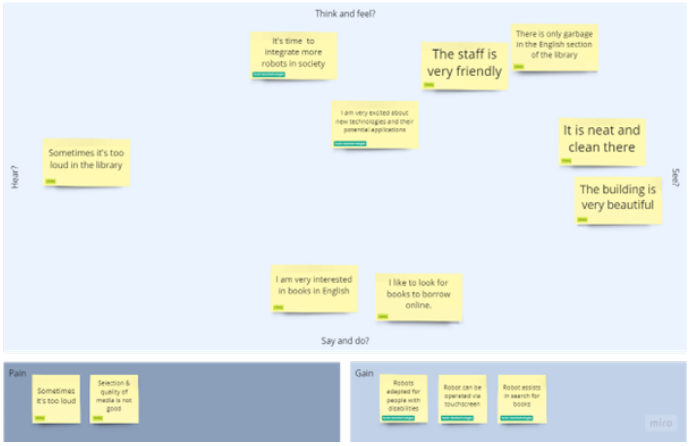

Fig. 3. Reference example of an empathy map corresponding to the "Marie" persona.

A.3 Storyboard - Example

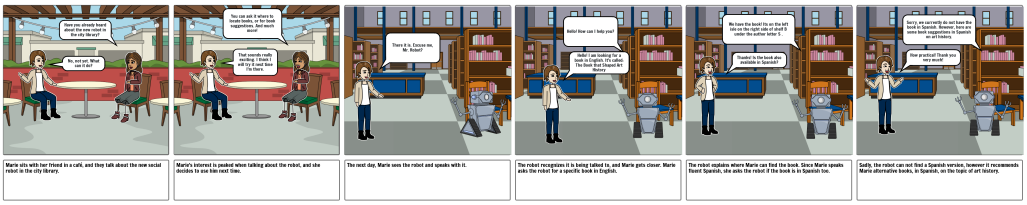

Fig. 4. Reference example of a storyboard corresponding to the "Marie" persona.

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