Technology Meets Tradition: Investigating User Acceptance and Engagement with Robots for Supporting Older Adults in Pakistani Homes

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Abstract

As Pakistan's population ages and traditional care structures evolve, there is increasing interest in technological solutions for supporting older adults at home. This study investigates the potential of social assistive robots (SARs) in Pakistani homes, focusing on cultural values, inter-generational living, and limited access to such technologies. In a 3-day mixed-methods home study, 14 older adults interacted with a SAR communicating in Urdu. Through observations, interviews, and questionnaires, we evaluated the robot's acceptability, engagement, and cultural compatibility. The results highlighted the need for culturally sensitive design, emphasising the role of robots as companions rather than replacements for human care, and the importance of robot's ability to communicate in Urdu. We discuss how SARs could be designed to reflect the characteristics of Pakistani households, including faith, family values, everyday routines, and environmental factors. Our design considerations can benefit research on deploying SARs to support older adults in Pakistan and similar cultures.

CCS Concepts

• **Human-centered computing** → *User studies*; *Collaborative interaction*; • **Computer systems organization** → *Robotics.*

Keywords

Human-Robot Interaction, Social interaction, Culture, Language, Pakistan.

ACM Reference Format:

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1 Introduction

In Pakistan, the ageing population is growing rapidly [89], presenting challenges in addressing the social, emotional, and practical needs of older adults [88]. Many older individuals experience loneliness and barriers to accessing services due to physical, practical, or social limitations [88, 94]. These challenges are exacerbated by evolving family structures [6, 41], as relationships between parents and children are often affected by migration, work commitments, or urbanisation [42]. While technology could help, supporting older adults in Pakistani households would require solutions that are culturally sensitive and technologically adaptable.

The integration of robotics in caregiving and companionship roles has gained traction globally [57, 107]; however, their application in culturally diverse [61] and linguistically specific contexts like Pakistan remains underexplored. Introducing a robot that communicates in Urdu and meets the needs of older adults in Pakistan offers a promising approach to improving their overall well-being [12, 58]. By communicating in their native language, understanding their culture, and addressing users' preferences, a social robot could provide companionship, assist with daily tasks, and enhance users' acceptance and engagement with the robots [10]. However, there is limited research on how such robots could be perceived within one's home. Therefore, our research explored Pakistani older adults' attitudes towards and engagement with an Urdu-speaking social robot in home environment and factors influencing its acceptance. We conducted a 3-day mixed-methods home study with 14 older adults to understand their expectations towards social assistive robots (SARs) and the potential impact of a robot on their households, and to identify the factors that influence acceptance and engagement.

Our work makes three contributions. Since this is, to the best of our knowledge, the first study to explore older adults' perceptions of social companion robots within their home settings in Pakistan, it enhances our understanding of how older adults perceive a social companion robot in their homes. Second, our research provides both empirical evidence and practical insights into the potential role of social robots in Pakistani households. Lastly, we provide recommendations to maximise the benefits of these robots for older adults in their home settings, as well as design considerations for researchers considering the deployment of robots in Pakistan and similar contexts.

2 Background

2.1 Technological Solutions for Ageing Populations: A Global Perspective

As global life expectancy increases [18] and fertility rates decline [96], many countries are experiencing rapid demographic shifts toward ageing populations. This shift presents significant challenges for healthcare systems, caregiving infrastructure, and social support networks [88]. In response, researchers are turning to technological innovations – including robotic solutions – as a means to support the independence, health, and well-being of older adults [21, 108].

Robots are increasingly used in older adults' care, serving a range of functions from physical assistance [16] to social companionship [5]. Such robots are broadly categorised as socially assistive robots (SARs), which are designed to help older adults perform daily tasks [35], monitor their health [16], remind them to take medications [13, 105], or simply provide conversation and reduce feelings of loneliness [15, 24]. For example, Ostrowski et al. [77] examined the long-term (12 months) use of SARs for older adults in their home settings in the USA. Their results show that the participants perceived the robot positively. Although there was a significant difference between initial and later interactions (due to the novelty effect), the older adults still recognised the robot's benefit in managing their daily routines and health. However, the question remains: are such robots suitable for everyone? To answer this, SARs are being tested in different regions around the world, particularly in Asia, to evaluate their potential value.

Asian countries like South Korea [57] and China [111] are beginning to integrate robotic technologies in everyday contexts and adapting them to local needs, languages, and caregiving traditions. This shows that the robots must not only function technically, but also align with the values, expectations, and communication styles of the communities they serve. However, countries across Asia have cultures, languages, and traditions that differ significantly from one another. For instance, in developing countries such as Pakistan, the ageing population is rapidly increasing [89], creating a growing need for technological support to promote independent living among older adults [69, 90]. However, the country's low literacy rate [48], little exposure to technologies [90], differences in sociocultural practices, and limited English proficiency highlight the importance of designing SARs that are culturally appropriate, available in the local language, and easy to use [12].

2.2 The Role of Language and Culture in Technology Acceptance and Engagement

As technological advancements bring social and assistive robots into more domestic environments [33, 40, 99], there is growing interest in how these tools can support older adults – particularly in ageing populations where caregiving resources may be limited [58]. In Human-Computer Interaction (HCI) and Human-Robot Interaction (HRI), researchers increasingly acknowledge that the success of such technologies is not purely technical but heavily influenced by the social environment, and linguistic [97] and cultural dynamics [64]. Among these, language and culture play an important role in how users perceive, interact with, and ultimately adopt new technologies [43, 76].

In the context of Pakistan, a multilingual country with deep-rooted cultural norms and a rapidly ageing population [89], the need for culturally adapted technologies is particularly important. While English is often the default language in technological interfaces, a significant proportion of older adults in Pakistan are more comfortable communicating in Urdu, the national language [12]. This language gap presents a barrier to accessibility, particularly for assistive technologies that rely on voice interaction [84]. Recognising this, recent efforts have focused on exploring robots capable of engaging with users in Urdu [12, 58]. However, designing such technologies requires more than linguistic translation; it demands a deep understanding of how language is connected to social expectations, emotional expression, and cultural norms [84].

Many studies suggest that the communicative relationship between humans and robots is the most important factor for engaging users and ensuring the acceptance of these technologies [22, 34, 60, 91]. Therefore, in our study, we evaluate the quality of interaction based on *effectiveness, efficiency, and user satisfaction* [71], as well as the mutual understanding established through both verbal and non-verbal communication. In this context, acceptance refers to the willingness of a user group to use technology for its intended tasks [32], which is closely linked to cultural, religious, and linguistic familiarity. In multilingual and religiously sensitive societies like Pakistan, where Urdu acts not only as a national language but also as a means of conveying religious beliefs and traditions, aligning the language of the technology with users' values fosters a sense of social inclusion [12, 58]. Previous HCI studies have shown that users are more likely to accept and adopt technologies that resonate with their socio-cultural contexts and communication preferences [92]. For example, Li et al. [62] highlights that culturally aware interactions, including support for native languages, as well as considerations of religion [14, 114] and social norms, help reduce cognitive and emotional barriers to technology adoption, hence increasing relevance and usability.

Engagement, on the other hand, is understood as *a collaborative process that reflects user involvement and interaction* [106], a definition that we adopt in this study. This, too, is enhanced by religious and cultural resonance, particularly when users can communicate in their native language. In many Muslim-majority settings, religion is deeply embedded in everyday communication, behavior, and decision-making [14, 72, 114]. HCI research has indicated that natural language capabilities, especially in underrepresented or local languages, significantly improve interaction depth, emotional involvement, and task continuity with social robots and digital agents [62, 67]. By enabling communication in Urdu, the robot not only accommodates linguistic diversity but also reinforces users' cultural identity. This creates a more immersive and participatory interaction experience [92] that is associated with sustained user attention and long-term engagement, particularly within caregiving contexts.

The adoption of robots would be further challenged by various other cultural factors, particularly in Pakistani households, where caregiving expectations can influence perceptions of a robot's role. Some may view it as a helpful tool, while others might see it as a threat to traditional family responsibilities [1]. To foster meaningful interactions without compromising usability, it's important for domestic SARs to adapt to contextualised interactions with older adults.

2.3 Opportunities and Systematic Barriers to Technology Adoption in Pakistani Households

Family has long been regarded as the cornerstone of Pakistani society [17], traditionally structured around the joint family system: a multi-generational household where parents, children, grandparents, uncles, aunts, and cousins often live together under one roof [112]. The joint family structure offers emotional security, shared responsibilities, and a built-in support system for caregiving, especially for children and the elderly [6]. However, in recent decades, Pakistan has seen a gradual but significant shift toward nuclear family structures, largely due to young people leaving their households to pursue better education or job opportunities in larger cities or abroad [42]. This transformation is reshaping the household dynamics, caregiving practices, and the roles assigned to elders in the household. It is also opening up new opportunities for technology adoption.

Pakistan is witnessing widespread technological changes. There has been a significant increase in mobile phone penetration, with more people gaining access to 3G and 4G services, even in remote areas [50]. Government-led digital inclusion programs, the expansion of e-commerce platforms, and growing awareness of technology-driven education and healthcare options are gradually changing public attitudes [55]. Moreover, the country has a large tech-savvy youth population [83], offering a foundation for future innovation and adoption, particularly if solutions are designed to be low-cost, locally relevant, and user-friendly. All of this opens up new avenues for supporting older adults: while in the past elderly parents could rely on regular daily contact and care from younger family members, many now experience social isolation [49]. Technology could help, although challenges remain.

While there are numerous technologies available to support older adults in developed countries, including robots, smart home systems, chatbots, or voice assistants [33, 40, 99], very few options exist for older adults in Pakistan. Furthermore, the adoption of such technologies in Pakistani households is uneven, influenced by a range of socio-economic and structural barriers. For example, one of the primary barriers to technology adoption in Pakistan is digital literacy [53]. A large segment of the population, especially among women and older adults, has limited literacy to confidently use digital devices, particularly when it comes to using them in English [12]. While younger generations tend to be more digitally fluent, older family members often struggle with technology-based solutions that are intended to assist them [83]. Infrastructure also presents a major barrier [74]. Inconsistent electricity supply and unreliable internet connectivity in rural and peri-urban areas hinder efforts to integrate digital tools into everyday life [110]. These gaps reduce the effectiveness of even well-designed technologies and create risks associated with dependence on them. For instance, smart home systems or health monitoring devices may become unusable during power outages or in areas with weak signals. Another barrier is cost [109]. Many households operate on limited incomes, making it difficult to purchase smartphones, laptops, smart home devices, or assistive technologies. Even when affordable options are available, the ongoing costs associated with these technologies, such as internet subscriptions, device maintenance, or electricity consumption, can pose challenges for long-term use, particularly in lower-income or rural areas [109]. However, despite these barriers, social robots could be a promising alternative for supporting older adults, especially when designed to align with cultural and linguistic needs. While they may not be affordable to everyone at present, the cost of technology typically decreases over time [4], and an increasing number of robotic technologies are becoming available on the market at lower prices [25].

Considering these opportunities and barriers, we aimed to understand the perspectives of older adults on using a culturally sensitive SAR that can engage with them in Urdu in their home settings. Our goal was to investigate their acceptance and engagement with the robot. By observing real-life interactions and gathering insights through robot interactions, questionnaires, interviews, and design activities, we aimed to enhance the robot's functionalities to better align with the needs and expectations of older adults in their home setting. To evaluate the impact of these enhancements, we formulated the following hypotheses:

- H1: Overall acceptance of the social robot among older adults will increase from the first to the last interaction.
- H2: Engagement with the social robot will remain stable (neither significantly increase nor decrease) from Day 1 to Day 3.

To evaluate these hypotheses, we collected data on user acceptance and engagement through questionnaires and performed video analysis to assess how engagement changes from Day 1 to Day 3. Together, these mixed methods enabled a detailed investigation of how acceptance and engagement with the robot developed across the three days.

3 Method

3.1 Research Context

3.1.1 Site selection. The study was conducted in the Lahore city district, the second largest city in Pakistan and the capital of the Punjab Province, with a population of over 7 million people. The decision to select an urban area for this study is based on the increasing prevalence of nuclear family systems in such areas [42], with many older adults living independently as their children often reside abroad for reasons such as education or employment [3].

3.1.2 Researchers positionality. All members of the research team are first-generation immigrants, with their families residing in their home countries. Two of the authors (R1 and R2) are originally from Pakistan and have lived abroad for over ten years. They possess a deep understanding of Pakistani culture, serving as both insiders and outsiders due to their current locations. Their experiences offered valuable insights into local systems, allowing them to communicate effectively with participants [98]. Additionally, their lived experiences informed the design of the activities and guided the preparation of the study materials, in particular the activity sheet (see Section 3.3.3). The other team members are interdisciplinary researchers with diverse backgrounds and extensive experience in conducting studies globally. They have worked in a variety of countries, including Bangladesh, Chile, Ecuador, India, Mexico, Peru, Somaliland, and South Africa. The collective experiences of the entire team have significantly influenced the study's development and the interpretation of its results.

3.2 Participants and Recruitment

In total, we recruited 14 individuals (7 men and 7 women) aged between 56 and 81 years old, with an average age of 68.5 years (SD = 7.74). All participants were educated to a level that enabled them to read and write fluently in both English and Urdu (see Table 1 for participants' details), allowing them to complete the activities on the activity sheet (reported in Section 3.3.3) and fill out the questionnaires independently. None of the participants had any prior experience using robots. Initially, we recruited participants through an advertisement on social media, and later used the snowball sampling method [81]. Subsequently, additional participants were recruited via word of mouth. The study was approved by the Ethics Committee of the lead author's institution in the United Kingdom (Project ID: COMSC/Ethics/2024/039).

3.3 Materials

3.3.1 Robot and speech. We used the SoftBank Robotics Nao robot [47] as our previous research indicated that older adults preferred it due to its spontaneous responses and fewer technical glitches [10]. To control its speech, we used the Wizard of Oz (WoZ) setup [70, 86]. We used TKinter, a standard Python library for creating graphical user interfaces (GUIs), which allowed us to develop the Wizard efficiently. We designed GUI with buttons corresponding to each activity for each day (see Supplementary Materials, Figures 2 and 3 for the Wizard of Oz GUI screenshots). As there is currently no Urdu language API for autonomous speech, we used 434 Urdu recordings using a female voice for robot speech using the text-to-speech platform from the Center for Language Engineering in Lahore, Pakistan [2]. Additionally, the autonomous mode of the robot was activated, enabling it to make eye contact with the participants and perform hand movements while speaking (see Figure 1a).

3.3.2 Questionnaires. We used five questionnaires. The *demographics questionnaire* assessed the eligibility of participants based on their age and proficiency in the Urdu language. We also collected information about their gender, education level, first and second languages, whether they own a phone, and what they use it for e.g., news, messaging, medication reminders. We also asked about their living situation and who their primary caregiver is. The *sociability assessment* questionnaire was based on [73] and included questions about participants' social activities, comfort in engaging with others, and preferred ways of starting or maintaining conversations. Their responses allowed us to evaluate participants' sociability levels and enabled the robot to provide tailored prompts to enhance conversation quality. We used the *technology acceptance model (TAM 2)* questionnaire [44] to evaluate users' acceptance. Based on prior literature [7], our main focus was on two parameters: perceived ease of use (PEOU) and perceived usefulness (PU). These two parameters were further categorised into perceived enjoyment (PE), perceived adaptability (PA), social presence (SP), trust (TR), perceived sociability (PS), and anxiety (ANX) [44]. The *engagement assessment questionnaire (EAQ)* was based on [78], and our aim was to primarily evaluate parameters such as focused attention (FA), felt involvement (FI), novelty (NOV), endurability (END), aesthetic appeal (AA), and perceived usability (PEU) to evaluate the engagement of the participants with the robot. Finally, the *language understanding questionnaire*, which was based on [68], aimed to evaluate the clarity of the robot's speech and the comprehensibility of the Urdu language. Questionnaires used in this study are provided in Tables 1, 5, 9, and 10 of the Supplementary Materials.

3.3.3 Activity sheet. To initiate interactions with the robot, participants were provided with an activity sheet designed for ice-breaking activities. It was available in both English and Urdu (see Supplementary Materials, Figure 1). The activities were categorised into five main types: informational, operational, learning, relational, and leisure, based on previous literature [77]. Although these activities were adapted from previous research [77], they were further refined to align with the Pakistani cultural and contextual setting based on our experiences. We chose them to maintain participants' interest during interactions, ensuring the activities were both meaningful and engaging. The informational category included activities such as providing weather updates, reciting verses from the Quran, and sharing interesting facts about Muslims. The operational category covered tasks like controlling the robot's head, hand, and standing movements, as well as setting medication reminders. The learning category involved educational interactions, including teaching the robot Urdu words, learning from the robot, and sharing fun facts about different months of the year. The relational category focused on social engagement, such as storytelling (for example, stories about Prophets), taking photos with participants, and chatting with the robot about participants' hobbies. Lastly, the leisure category consisted of engaging games, including a "guess the age" activity where the robot and participants guessed each other's ages, and a "circuit saver" memory game in which participants recalled word sequences in the correct order, with the level of difficulty increasing from three to eight words.

3.4 Study Setup

The study took place in the participants' homes. We requested that the environment be quiet, with minimal distractions, with a comfortable chair for the participant and a table on which the robot could be placed in a sitting position at the participant's eye level; the robot only stood when participants requested it during activities (see Fig. 1), otherwise it remained seated. Two researchers (R1 and R2) sat at a distance from the participant and the robot. R1 (first author) was controlling the WoZ setup, while R2 (second author) focused on making observations, taking notes and providing

ID	Gender	Age	Living Status	Education	Sociability
P1	F	71	Widow, with son	BA	3.5
P2	F	71	Widow, with son	FA	4.0
P3	M	75	With wife, children abroad	PhD	3.625
P4	M	78	With wife, children abroad	BA LLB	2.875
P5	F	56	With son, husband abroad	BSc BEd	3.125
P6	F	81	Widow, with son	FA	4.375
P7	F	62	With husband and children	MA BEd	3.625
P8	M	69	With wife, children abroad	MBBS	3.625
P9	F	62	With husband, children abroad	PhD Botany	3.125
P10	F	59	With husband and children	BA	2.75
P11	M	72	With wife, children abroad	BSc Electrical	3.875
P12	M	67	With wife, children abroad	CA	3.25
P13	M	59	With wife, children abroad	MSc Electrical	3.875
P14	M	75	With wife, children abroad	PhD Psychology	3.125

Table 1: Participants' details, education level (abbreviations: FA = Post-Secondary (Arts), BA = Bachelor of Arts, BSc = Bachelor of Science, BEd = Bachelor of Education, MA = Master of Arts, MSc = Master of Science, PhD = Doctorate, BA LLB = Bachelor of Arts and Law, MBBS = Medicine, CA = Chartered Accountancy), and sociability scores [73], reflecting individual social tendencies (0–5 scale; higher scores indicate greater sociability; see Section 3.3.2 for details).

technical support. Participants were explicitly informed beforehand that the robot was not autonomous and that both its speech and movements would be controlled by the researchers.

3.5 Pilot Study

We conducted a pilot study with an Urdu-speaking individual in their home in the UK to test the robot, WoZ controls, room setup, and procedures. As a result, we added improved goodbye phrases and a three-second pause between the robot's responses to allow for participant input without interruptions. Additionally, based on pilot observations and conversations with pilot participant, we designed a front pocket on the robot to hold a medication box, making the interaction more practical and personally relevant for older adults who manage daily medications (see Figure 1a).

3.6 Procedure

We conducted the study between July and August 2024 over the course of three consecutive days for each participant, with each day's activities taking on average 40-70 minutes. See Table. 2 for an overview and the following sections for more details.

3.6.1 Day 1. The session began with a brief introduction of the researchers and an overview of the study. Participants were informed that all robots' responses would be in Urdu. Then, they were asked to sign the informed consent form and to read a participants information sheet about the study. Next, they completed demographic and sociability assessment questionnaires. We then provided an activity sheet to facilitate conversations. Following the initial conversations, the robot encouraged the participant to share details about their daily routines, including health conditions, dietary preferences, medications and who helps to manage them, which enabled a discussion on robot's potential role at home. The robot also offered a language-learning opportunity by asking participants if they wanted to learn English or Arabic, as their holy book, the Quran, is in Arabic. All participants chose Arabic, and the robot taught them five words with their meanings, encouraging them to remember. At the end of Day 1, the participant completed TAM 2 and EAQ questionnaires.

3.6.2 Day 2. After the initial greetings, R1 provided a brief introduction outlining the day's activities. The participant then engaged in design activities with R1, which took approximately 35-45 minutes to complete (see Figure 4 in Supplementary Materials for an overview of the design activities). The purpose of the design activities was to gain insights into how participants imagine a robot fitting into their homes and daily lives, encouraging them to think of practical and meaningful ways the robot could support or improve their everyday activities. During the design activities, the participant first completed a diary activity, followed by a home layout activity. After that, they engaged in an activity called "MyRobot, MyDesign," where they envisioned their robot's appearance and functionalities (see Table 11 in Supplementary Materials for the prompts guiding the design activities). This process was guided by design cards that presented various options for robots' body types and functionalities (reported separately in Ahmad et al. [11]). Following the design activities, they had a brief conversation with the robot. We aimed to personalise the conversations based on Day 1 interactions. Therefore, the robot discussed participant's social activities and friendships, recalled their fond childhood memories, and provided medication reminders based on the information shared earlier. Next, the robot inquired about the Arabic words the participant had learnt and introduced five additional words along with their meanings. At the end of Day 2, the participant filled out a language understanding questionnaire and shared their brief opinions and suggestions regarding their experiences with the robot so far.

3.6.3 Day 3. At the beginning, R1 gave a brief overview of the day's activities. Similar to Day 2, we aimed to make the interactions more personalised by discussing the habits, likes, and dislikes of each participant based on their earlier responses. The session began with the robot reminding the participant about their medication,

(a) (b)

Figure 1: Left: Robot used during the study. A vest and a medication box were added to help older adults relate to it and remember their medications. Right: Examples of the study setup, with the robot interacting with the participants during the study.

Day 1 (45-60 min.)	Day 2 (50-70 min.)	Day 3 (40-55 min.)
Introduction and Pre-study Questionnaires (10–15 min.)	Design Activities (35–45 min.)	Robot Interaction (10–15 min.)
Robot Interaction (25–30 min.)	Robot Interaction (10–15 min.)	Post-study Questionnaires (15–20 min.)
Post-study Questionnaires and Debrief (10–15 min.)	Post-study Questionnaires and Debrief (5–10 min.)	Interview (15–20 min.)

Table 2: Overview of key activities for each day of the study.

followed by a Quran reading activity. Following that, the participants were asked about the meanings of 10 Arabic words they had learnt over the past two days. The robot praised their efforts and offered encouragement. Next, the robot introduced additional memory games. Then, based on the participant's preferences expressed earlier, the robot led discussions related to their hobbies (e.g. favorite TV shows, books, gardening, cooking, singing, sewing, knitting, drawing, or painting). To conclude the session, based on findings from our previous studies (currently under review), we wanted the robot to incorporate some religious phrases, such as "InshaAllah" and "MashaAllah," into its speech. We asked the participant for their thoughts on the robot using these expressions. Afterward, we wrapped up the session by giving the participant three post-study questionnaires: the TAM 2, EAQ, and a language understanding questionnaire. We also conducted final interviews (approx. 15-20 minutes) to discuss their experiences with the robot throughout the three days, including suggestions for improvements and their perceptions of having a robot at home, e.g. to remind about medications or provide them company (see Supplementary Materials Table 12 for the interview guide). At the end, the researchers provided the participant with incentives (PKR 10,000, approx. £25) and expressed their gratitude for their participation.

3.7 Data Analysis

3.7.1 Questionnaires analysis. To analyse the sociability questionnaire, we calculated the average scores. Higher scores indicate greater sociability. Our participant pool had an overall average sociability score of 3.68 out of 5, suggesting a relatively high level of sociability (Table 1).

To analyse TAM 2 and EAQ results, we first assigned scores to each response in the questionnaire, where "Strongly Disagree" corresponded to a score of 1, and "Strongly Agree" was assigned a score of 5. Next, we calculated the Cronbach's Alpha value [27] for each TAM 2 and EAQ parameter, as well as for the overall data, to assess the reliability. The Cronbach's Alpha value was 0.70 for the overall TAM 2 scores both on Day 1 and Day 3, and 0.69 for overall EAQ scores both on Day 1 and Day 3 (a Cronbach's Alpha value of at least 0.7 is considered reliable [44]). All individual Cronbach's Alpha values are provided in Tables 2 and 6 of the Supplementary Materials. Following this, we conducted an analysis of descriptive statistics to gain an initial understanding of our data. Then, we computed correlations between each acceptability and engagement parameter to explore any significant relationships between them. Finally, we conducted a repeated measures ANOVA, using day number of the interaction as a within-subject variable for all individual measures of the acceptability and engagement parameters, to determine any differences in the way participants interacted from Day 1 to Day 3.

To assess participants' perceptions of the robot's language comprehension, we used a Likert scale for the language understanding questionnaire, with "1" representing no understanding and "5" indicating full understanding.

3.7.2 Interview analysis. All the interviews were conducted in Urdu. The recordings were transcribed in Urdu before being translated into English by R1 to facilitate discussions with other team members. R2 cross-checked the transcriptions to ensure accuracy and consistency in the translations.

As we were interested in specific topics (such as older adults' expectations of social robots, preferred roles in daily routines, and cultural considerations), the interviews were analysed using inductive thematic analysis, following an approach based on framework analysis [87]. We adopted the same methodology as described in [102]. After becoming familiar with the data, two researchers (R1 and R3, the last author) summarised the transcripts in a framework table using Microsoft Excel to identify potential themes. In this table, each row represented an individual participant, while each column reflected their responses to different interview questions. This tabular format made it easy to compare and contrast the data across participants and questions, allowing us to identify key trends and codes. To do so, we summarised the content of each column and examined similarities across the table to identify recurring patterns and themes, which were discussed with the rest of the research team, leading to the development of initial themes. Finally, the links and common trends were identified by R1 based on the completed table and discussed with R3 to describe the key themes focused around the cultural alignment and role of language in connecting with robot, holistic and routine-centered care, and family influence and generational perspectives. The final themes were then discussed and further developed by all authors during the work on this manuscript.

3.7.3 Video analysis. We collected approximately 700 minutes of interactions. Each video was independently coded using ELAN [113] by R1 and cross-checked by R4, the third author. We categorised the video data into three distinct categories: smooth interactions (seamless conversations and activities), problematic interactions (such as delays in the robot's responses, misunderstandings in the robot's communication, or other technical difficulties), and unusual interactions (instances where participants began speaking to the researchers instead of the robot). We employed a moment-by- moment coding and observations technique to analyse smooth interactions [23]. For our moment-by-moment coding, we aimed to measure participants' verbal and non-verbal interactions during the sessions. Verbal interactions were coded based on the verbal responses participants provided to the robot, while non-verbal engagement was coded based on factors such as gaze (i.e., instances when participants looked at the robot during interaction), facial expressions, and gestures (i.e., movements of the hands or head) [9, 36]. To code gaze, we used systematic observation measures, noting both the frequency and duration of participants looking at the robot to capture sustained attention as well as brief glances. Facial expressions were coded by identifying observable affective cues (e.g., smiles, frowns, raised eyebrows) and noting their occurrence to assess participants' engagement. For gestures, we coded hand and head movements, distinguishing communicative gestures (e.g., nodding, pointing) from incidental movements, and coding their frequency within the interaction [10, 23]. To analyse problematic and unusual interactions we focused only on observations. Given that the duration of interaction sessions varied across the three days, raw data was normalised by calculating the proportion of each engagement measure relative to the total interaction time, which ensured consistency and allowed for reliable comparisons across sessions. Following normalisation, we computed the average values for each engagement indicator per day to observe trends over time.

In our observations, we focused on how participants "do" social interactions with the robot. We aimed to understand how these interactions evolved over time in order to identify patterns of engagement. Based on work by Jarske et al. [51], we were also interested in knowing if participants were responding to the robot out of obligation, or if they were genuinely pleased to engage. This distinction was important because we wanted to ensure that the interactions were meaningful rather than simply a result of social politeness. To evaluate this, we observed participants' behavior and verbal cues. Furthermore, we also observed whether they interacted with the robot as they would with a person, employing courteous expressions, pausing for replies, or checking comprehension, similar to their behavior with humans – as opposed to regarding the robot as a device, bypassing social norms, and showing frustration with its constraints. Finally, we conducted a repeated measures ANOVA test with interaction day number as a within-subject variable for gaze, verbal interaction, facial expressions and gestures, to determine any differences in the way participant interaction from Day 1 to Day 3.

4 Results

4.1 User Acceptance – TAM 2 Results

To test H1, we conducted a repeated measures ANOVA with day as an independent variable and all TAM 2 individual measures as dependent variables. We found that ANX (F(1,13) = 19.74, $p < 0.05$) significantly dropped from Day 1 to Day 3. Similarly, PEOU (F(1,13) = 10.42, $p < 0.05$) improved significantly from Day 1 to Day 3. However, we did not observe significant differences for other variables, such as PE, PA, SP, TR, PS, and PU. The significant increase in PEOU and decrease in ANX from Day 1 to Day 3 clearly demonstrate that participants' acceptance of the robot improved over the three days, in line with H1.

Figure 2 presents mean scores for each TAM 2 parameter. We observe that although TR did not increase statistically significantly, there was a noticeable upward trend, rising from 3.75 (SD = 0.50) to 3.90 (SD = 0.51). This suggests that continued interaction may have positively influenced participants' confidence in the robot. Likewise, PU increased to a mean of 4.02 (SD = 0.59), indicating an enhanced recognition of the robot's potential to positively contribute to daily life. Lastly, the consistent values for the other TAM 2 variables indicate a stable level of acceptance.

To further examine the relationships among the parameters of the TAM 2, Pearson correlation analyses were conducted separately for Day 1 and Day 3 (See Supplementary Materials, Tables 3 and 4, for separate tables.). The correlation matrix for Day 1 revealed generally weak and statistically non-significant relationships among most TAM 2 parameters. The only statistically significant positive correlation was found between PS and SP ($r = 0.594, p < 0.05$). This shows that participants who perceived the robot as more social (i.e., friendly and emotional) also saw it as being more socially present, as if the robot was there with them in a social and interactive manner. Another notable relationship was observed between PU and TR ($r = 0.787, p < 0.01$), suggesting that participants who trusted the robot were more likely to perceive it as useful. Other correlations, such as those between PEOU and PA ($r = -0.324$) or between PE and TR ($r = -0.272$), were weak and not statistically significant. This suggests that, at this early stage of robot exposure, participants' perceptions were still forming and were not yet strongly interconnected.

By Day 3, the correlations changed significantly, revealing stronger and more meaningful relationships among the variables. Notably, PE demonstrated strong, statistically significant positive correlations with TR ($r = 0.814, p < 0.01$), PS ($r = 0.711, p < 0.01$), and PU ($r = 0.704, p < 0.01$). This pattern indicates that as participants became more familiar with the robot, their enjoyment was closely related to how much they trust the robot, how socially capable they perceived it to be, and how useful they found it. Similarly, Trust was positively correlated with SP ($r = 0.618, p < 0.05$) and PU ($r = 0.638, p < 0.05$), reinforcing the importance of trust in shaping overall acceptance. However, trust was negatively correlated with PEOU ($r = -0.651, p < 0.05$), suggesting a potential shift in the user evaluation process; as users gained experience, trust may have emerged more from relational or affective factors (e.g., social presence) rather than from simple usability. Furthermore, SP was significantly associated with PA ($r = .534, p < .05$), reflecting a growing perception that socially responsive robots are also more adaptable to users' needs and contexts. These results illustrate the dynamic nature of users' perceptions over time. The stronger and more coherent correlation patterns on Day 3 suggest that continued exposure to the robot not only reduced anxiety but also increased acceptance among users. Parameters such as trust, usefulness, and enjoyment became more interrelated, highlighting the importance of sustained interaction in the adoption of technology among older adults.

4.2 User Engagement – EAQ Results

To test H2, we conducted a repeated measures ANOVA with day as an independent variable and all EAQ individual measures (FA, FI, NOV, END, AA, and PEU) as dependent variables. We found that FA (F(1,13) = 4.61, $p < 0.05$) and FI (F(1,13) = 5.50, $p < 0.05$) significantly increased from Day 1 to Day 3. However, we did not observe significant differences for other variables, such as NOV, END, AA, and PEU. The significant increase in FI and FA from Day 1 to Day 3 demonstrates sustained interest and curiosity in the robot, suggesting that engagement with it increased over time, in line with H2.

Figure 3 presents the descriptive statistics of mean scores for each EAQ measures, collected on Day 1 and Day 3 of the study. We observed several changes in user perceptions. FI increased to a mean score of 4.10 (SD = 0.27), indicating better emotional involvement in the system over time. PU also showed a slight improvement (M = 3.02, SD = 1.20), although it remained the lowest-rated measure, suggesting ongoing usability concerns. Other metrics, such as NOV (M = 3.85, SD = 0.54) and END (M = 3.71, SD = 0.59), remained consistently positive, reflecting sustained user interest and a willingness to continue using the system. These results suggest a general trend of increased user engagement with the system over time, though there continues to be room for improvement in usability.

Pearson correlation coefficient tables among the six user engagement parameters are provided in Tables 7 and 8 of the Supplementary Materials. On Day 1, correlations had several statistically significant relationships that emerged between the different engagement constructs. NOV was strongly and positively correlated with FA ($r = .701$, $p = .005$), FI ($r = .789$, $p = .001$), and END ($r = .786$, $p = .001$). This suggests that perceived users' attention and involvement with the system play a major role in facilitating users' experience. Additionally, END exhibited significant associations with FI ($r = .695$, $p = .006$) and FA ($r = .599$, $p = .024$), indicating that more engaging and emotionally resonant experiences are often those perceived to have lasting value. AA was moderately correlated with NOV ($r = .557$, $p = .039$), reinforcing the link between visual design aesthetics and the perception of innovation within the system. PU did not show any significant correlations with the other engagement parameters and was negatively associated (though non-significantly) with FA ($r = -0.494$, $p = .072$) and other parameters. This suggests a potential trade-off during initial

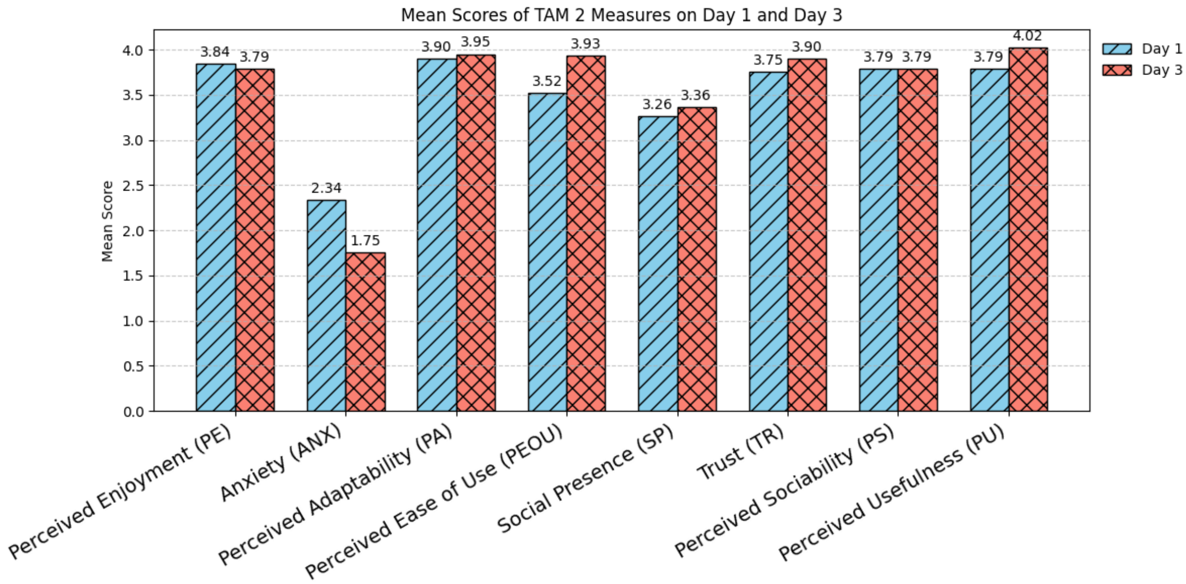

Figure 2: Mean Scores of TAM 2 Measures for Day 1 and Day 3.

interactions, where higher usability might not necessarily lead to deeper engagement.

On Day 3, a similar pattern of correlations was observed, although some noteworthy changes occurred. NOV continued to be significantly correlated with FI (r = .721, p = .004) and END (r = .801, p = .001), maintaining its essential role in creating engaging and good user experiences. END also correlated significantly with FI (r = .687, p = .007), consistent with the findings from Day 1. In contrast to Day 1, FA did not exhibit any statistically significant relationships with the other parameters, suggesting a possible decoupling of attentional focus from other experiential dimensions as users became more familiar with the system. Once again, PU did not show significant correlations with any parameters, reinforcing its independence from the emotional and cognitive components of engagement across both days. Overall, the results indicate that while certain dimensions of engagement (such as Novelty, Endurability, and Felt Involvement) remain interrelated over time, the role of usability in contributing to a deeply engaging experience may be more limited or context-dependent during initial interaction scenarios.

4.3 Users' Engagement and Logistical Insights from Video Analysis

To assess participants' engagement during their interactions with older adults, we conducted a systematic video coding process focusing on four behavioral indicators: gaze, gestures, verbal responses, and facial expressions. Table 3 presents the normalised proportions of each engagement parameter across the three days of interaction. To further test H2, we conducted a repeated measures ANOVA with day as an independent variable and all user engagement measures such as gaze, gestures, verbal responses and facial expressions as dependent variables. We found that gaze ($F(1,13) = 6.74$, $p < 0.05$) declines significantly across days. Post hoc tests reveal that while gaze declined significantly from Day 1 to Day 2, it did not differ significantly from Day 2 to Day 3, suggesting that gaze value becomes more consistent from the second day. We did not observe significant differences for other variables, suggesting that verbal interaction, facial expressions, and gestures stayed consistent across the three days. This indicates that engagement remained consistent throughout the three days, in line with H2, which was also reflected in the EAQ results. A significant decrease in gaze was noted from Day 1 to Day 3. During their initial interaction with the robot, participants tended to focus more on it in the first session. As they became familiar with the robot, their gaze became steadier and remained consistent starting from Day 2.

Apart from the quantitative measures, the video analysis revealed environmental and robot-related factors that could have disrupted the interaction, but instead became a prompt for re-engagement. For example, there were occasions when participants questioned if the robot was appropriate for the local environment, especially when it encountered technical issues. Since the study took place during the hot mid-summer season, the robot frequently gave warnings such as *"My motors are getting hot"*, which made the participants discuss whether the robot could stay in Pakistan. There was a concern that the weather might pose a significant technical challenge, leading to discussions about the robot's practicality.

The analysis of the interactions also revealed the types of tasks a robot could handle and participants' reactions to robot's limitations. For example, during one interaction, P13 asked the robot if it could help carry something across the room. When the robot failed to respond due to its lack of movement functionality, the participant laughed and said, *"Oh, so you're just pretty to look at then?"* Despite this letdown, the comment was made with a smile,

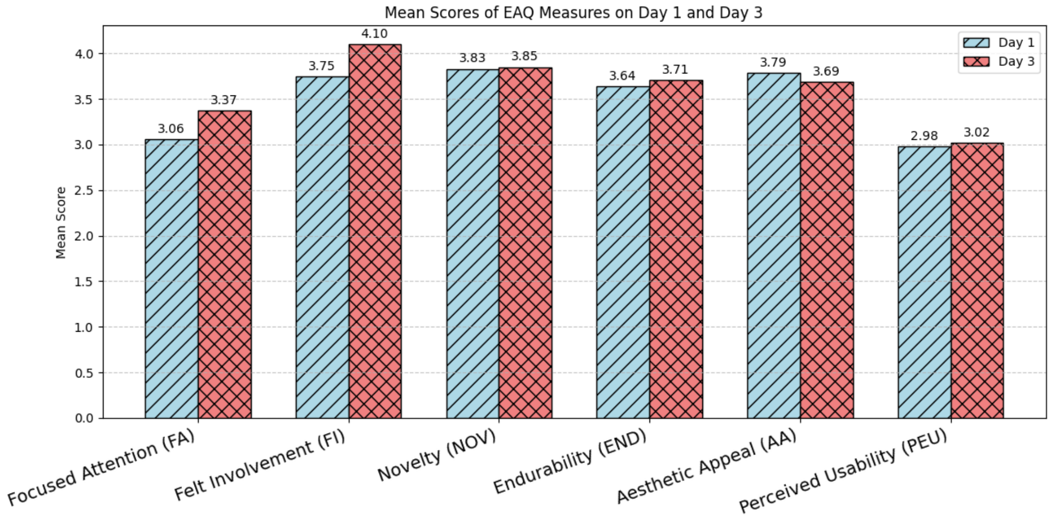

Figure 3: Mean Scores of EAQ Measures on Day 1 and Day 3.

	Gaze (ss.msec)	Gestures (ss.msec)	Verbal Responses (ss.msec)	Facial Expressions (ss.msec)
Day 1	0.8079	0.0020	0.4325	0.3650
Day 2	0.6513	0.0050	0.4188	0.2475
Day 3	0.5941	0.0055	0.3647	0.2114

Table 3: Normalised engagement metrics over time for all participants

and the participant continued the interaction by asking the robot to tell a joke instead, adjusting the task to align with the robot's capabilities. This flexibility demonstrates a willingness to maintain a social connection, even when the robot's functionality falls short.

In a few cases, we observed that when the robot did not meet participants' expectations due to technical limitations, such as limited speech or restricted mobility, participants did not abandon the interaction. Instead, they often expressed mild disappointment humorously or affectionately and then shifted to a supportive coaching approach. For example, P10 said, *"That's fine. I can teach you"*. Similarly, P14 expressed frustration more directly, saying, *"Does this mean it'll take you 20 more years to help me?"* after the robot struggled to understand a question. However, rather than withdrawing, the participant began to repeat their question slowly, articulating each word with greater clarity. They then followed up with the prompt, *"Do you understand now, beta?"*, using the affectionate Urdu term meaning "child." This not only reframed the robot as a learner, but also positioned the participant in a nurturing, parental role. P14 later remarked, *"I understand that the robot is still learning and has a lot to learn from us humans."*

Participants modified their communication style by slowing down their speech, simplifying vocabulary, or providing step-by-step instructions. In one instance, a participant (P7) even offered feedback to the robot: *"You should practice more. Next time, you'll do better, Inshallah."* The use of "Inshallah" (God willing) infused the robot's future improvement with a culturally significant expression of hope and optimism. These reactions indicate that disappointment did not disrupt the interaction; instead, it resembled a relatively positive mentoring approach, revealing how older adults were not merely using a tool, but were actively engaged in a relational process where the robot was seen as having the potential to learn and grow.

4.4 Participants' Perceptions Based on Interviews and Observations

In this section, we present the results of the interview analysis and general observations. We identified three themes centred around different aspects of culture and its impact on Pakistani households: the role of cultural alignment and companionship in connecting with the robot, the importance of culture-centred holistic care, and the need to incorporate family and generational perspectives.

4.4.1 Role of cultural alignment and companionship in connecting with the robot. During the interviews, the participants particularly focused on the extent to which the cultural alignment and language of the robot affected their willingness to engage and understand it. They frequently highlighted that when the robot communicated in their native language, it greatly enhanced their experience and helped them feel more confident:

> "When the robot speaks my language, it feels like I'm talking to someone who understands me. I can follow what it's saying without thinking too hard about it." (P9)

> "Hearing the robot speak Urdu made me feel like it truly understood us, like it was part of our family." (P10)

Building on the cultural values, religious norms also play an important role in the daily lives of many Pakistanis, especially older adults. As such, our participants believed that a robot should also incorporate religious knowledge to support their spiritual well-being. They thought the robot could provide guidance on Islamic practices, such as reminding them of prayer (Salah) times, offering more Quranic recitations, and sharing Hadith-based health advice that aligns with their beliefs (more on this in the next section), as this would make the robot more culturally and spiritually relevant. Some expressed a desire for the robot to help with learning supplications (duas) for health and well-being or providing gentle reminders about ethical and moral teachings in Islam.

> "It should remind us of prayers and help with counting Tasbeeh [Arabic term used to describe the practice of praising Allah]." (P13)

Since companionship plays an important role in the later stages of life, we observed multiple recurring patterns in which participants perceived the robot not merely as a device, but as a potential companion. In one instance, P3 initiated conversation by softly calling the robot's name and making a subtle gesture to signal interest. This behavior resembled the normal practice of "catching someone's attention," similar to how eye contact is used to initiate conversation among humans. In another instance, P3 was observed sitting quietly with the robot after a lengthy conversation, simply resting their hand near it as if to maintain a sense of companionship. This initial phase of engagement was sometimes brief, consisting of a quick glance or nod, but it could also be extended, especially when participants were uncertain whether the robot had registered their presence, particularly when it was not looking at them. In such cases, they would repeat the robot's name more loudly, lightly knock on a table, or even shift their body towards it to prompt a response. These cues reflect the common interaction norms, where initiating conversation often begins with polite invitations like *"Are you listening?"* or *"Shall we talk?"* The tone during these moments was typically warm and occasionally playful, indicating a desire to create a light, social atmosphere with the robot. Once a sense of mutual connection was established, whether through the robot's verbal acknowledgment or its gaze, participants frequently smiled, sat up straighter, or made affirming remarks such as *"Let's do this"* when invited to start a joint activity like language practice or storytelling. These verbal and nonverbal actions can be seen as a symbolic offering of companionship – an invitation for the robot to participate not only in conversation, but also in meaningful shared activities.

Although the robot had limited capabilities, participants viewed it as a willing companion, an entity to converse with. Many used it as a vent for conversation, often not expecting sophisticated replies, but rather valuing the simple act of speaking and being "heard." One example involved a participant (P10) who recounted the plot of a novel in great detail, carefully explaining the characters and their relationships. When asked afterward why they had elaborated so thoroughly, the participant explained, *"It's not like [the robot] gets it all,"* but expressed happiness in the fact that the robot was listening. This highlights the potential of the robot to provide a sense of companionship to older adults when needed. In another instance, P14 directly expressed frustration at the robot, saying, *"Does this mean it'll take you 20 more years to help me?"* after the robot struggled to understand a question. However, rather than withdrawing, the participant began to repeat their question slowly, articulating each word with greater clarity. They then followed up with the prompt, *"Do you understand now, beta?"*, using the affectionate Urdu term meaning "child." This not only reframed the robot as a learner, but also positioned the participant in a nurturing, parental role. P14 later remarked, *"I understand that the robot is still learning and has a lot to learn from us humans."* Another participant (P8) spoke to the robot about their daily routine, sharing small personal stories and occasionally pausing for a response, even when it was delayed or generic. When the robot offered a pre-programmed affirmation, the participant smiled and continued the conversation as if engaging with a real person. At one point, they reached out and gently touched the robot's head, saying, *"You don't talk much, but you're a good listener."*

Further in the discussions about companionship, all participants emphasised the significance of maids (house help) in Pakistani culture and how they provide valuable companionship and caregiving to older adults. Many households employ either live-in or visiting maids, and participants view these helpers as part of the family:

> "I still feel that the house help in Pakistan is inexpensive. There are plenty of things to do in any home but I think human help cannot be replaced. Even as a companion or caregiver, house helps are really good and they bring news from all the town to your house and keep you entertained." (P2)

Participants expressed uncertainty about how a robot would fit into households that already have human help, such as household maids. There was a sense of ambiguity around how the robot would be perceived and treated within such social dynamics. As one participant said:

> "In our house, maids are treated with respect; how do we see a robot? "(P12)

This raises deeper cultural and ethical questions. Given that domestic workers are treated with respect, where does a robot fit into the household hierarchy? Would it be seen as a tool, a servant, or something in between? Another concern that was raised was that the presence of a robot might unintentionally create insecurity among household maids. One participant (P3) pointed out that they might feel threatened by the robot, fearing it could replace their roles or diminish their value within the home. This means that the integration of robots into domestic environments is not merely a technical issue; it is also closely tied to existing social structures, labor dynamics, and cultural values surrounding respect and roles in the household.

4.4.2 Importance of culture-centered holistic care. Participants discussed how the robot could assist older adults not only in managing their medications but also in promoting a healthier lifestyle overall. They expressed a strong preference for robots supporting holistic and routine-based approaches for their health management, emphasising the significance of daily practices and traditional wellness methods over medical interventions. In particular, they highlighted the significance of integrating cultural and traditional practices with modern healthcare to create a balanced and sustainable approach to well-being. Instead of overly depending on prescribed medication, they preferred managing their well-being through lifestyle adjustments that align with their cultural and generational practices. One participant explained:

> "I have been following my morning herbal tea routine for years, and it keeps me feeling energetic. I only take medicine when absolutely necessary." (P3)

In this context, participants imagined the robot could serve not just as a medical assistant, but also as a supportive companion that would encourage and reinforce holistic and culturally relevant practices by assisting with daily routines, promoting traditional wellness methods, and aligning with participants' values and lifestyles. It could offer gentle reminders and personalised encouragement to help manage their health without relying solely on medication

> "I believe in a healthy routine rather than relying on medications. I'll be happy if a robot can help me with my routine." (P14)

> "I am not a big fan of medications. I think I will find my way to sneak out whenever it's my medication time. But the robot could still remind me about it in new ways." (P12)

While some participants focused on their attitudes toward medications (two participants admitted that they disliked swallowing tablets), others emphasised the broader role of cultural and religious traditions in their health and well-being. They believed that by integrating religious knowledge with healthcare support, the robot could go beyond being just a medical device to become a trusted companion aligned with their faith, making it more meaningful and widely accepted. A number of participants also highlighted how religious and spiritual practices, such as prayer and meditation, play a vital role in their daily health routines. For older adults, especially, linking medication reminders to prayer times could offer a familiar and effective way to manage their medications, particularly for those less comfortable with modern reminder technologies. One participant said:

> "I myself am a doctor and I know that with the general public who are not literate, it is harder to help them remember. I tell them that they have to take the medications before or after the prayer time. [Muslims pray 5 times a day], so it is easier for most of the people to remember according to prayer times." (P8)

Participants also drew a comparison between Pakistani culture and the Western world, emphasising the distinct ways in which social values, healthcare practices, and technology adoption differ between the two. They noted that in Pakistan, healthcare decisions are often influenced by family, whereas in the Western world, individuals are more likely to make independent health choices. The participant also highlighted the difference in doctor-patient relationship, explaining that in Pakistan, patients tend to expect a more personalised and emotionally supportive interaction, while Western healthcare is often seen as more transactional and efficiency-driven. Additionally, they pointed out that Western societies are generally quicker to embrace new technologies in healthcare, whereas in Pakistan, there is often a greater reliance on traditional practices. One participant mentioned:

> "It [the concept of robot] is overall good. But probably for Western scenarios. In Pakistan, it may not be suitable because of family structures." (P14)

4.4.3 Incorporating family and generational perspectives. Participants believed that the presence of a robot could also benefit other family members. As managing medications and other routines could be challenging both for them and their caregivers (children) due to their own hectic schedules, a robot could help reduce the burden on family members and provide support when needed. They suggested that its presence could allow family caregivers to work without worrying about their parents being alone at home. Additionally, the robot could give family members a daily overview of the older adults' routines, ensuring that nothing is forgotten. It could also act as a full-time caregiver when family members are not available.

> "My daughter reminds me sometimes, but she forgets too. The robot will never forget." (P5)

Five participants mentioned that even when living with their children, there were still times when they were alone at home, especially during working hours. In these situations, robot's company and support may still be needed. Two participants emphasised that children should recognise when older parents need assistance at home alone, rather than resist technologies like robots.

> "I feel even in the combined family system, when the children go to work and grandchildren go to their schools, even then the older adults are alone in their home. They need someone, or they may need someone for an emergency. Children need to understand that." (P1)

Additionally, participants believed that the robot could help strengthen the relationship between grandparents and their young grandchildren. Some noted that when their grandchildren learned that they were visited by a robot companion during the study, it brought them joy to know that there was someone available to support their grandparents when no one else was around.

> "Even my little granddaughter started talking to it. She would ask it [the robot] to remind me about my tea." (P5)

> "My grandson was laughing, saying 'Dadi [grandma in Urdu], now you have a robot friend!' But I think he was just happy for me that I had company." (P9)

However, participants also expressed concerns about children potentially damaging the robot, as their curiosity might lead to rough handling or pressing buttons. In many Pakistani households with extended families, young children have easy access to shared spaces, increasing the risk of accidental damage. Some questioned the robot's durability and the availability of repair options. While they appreciated its benefits, they emphasised the need for childproofing measures and a sturdy design to ensure its usefulness in a home setting.

> "I don't think it'll be useful. Children will break it in a day." (P4)

On the other hand, some participants expressed difficulty in envisioning how a robot could fit into a household in the first place, questioning its role. Moreover, they noted that the presence of multiple individuals could create confusion about who interacts with or is responsible for the robot, which would complicate its integration into daily routines. This indicates that, when designing robots for domestic use, it is important to consider not only individual users, but also wider household structures.

> "Combine families have so many people in one home. There will be no space for the robot. (P10)"

> "I mean, how can a machine replace a human? In a family, we help each other." (P13)

5 Discussion

As Pakistan experiences an aging population and shifts in traditional family caregiving structures, SARs emerge as a potentially valuable yet complex solution. While existing studies have examined the acceptance and engagement of robots in controlled lab settings [28, 54], there remains a notable gap in research focused on how older adults in real Pakistani home environments perceive and interact with these technologies. Therefore, our study aimed to investigate how social robots could assist older adults at home within the context of Pakistani households. To this end, we conducted a home-based study with 14 older adults in their home settings, who engaged with a robot in Urdu. While we focused on their perceptions of the robot in these environments, our findings also revealed how sociocultural norms, household dynamics, and traditions shaped their perceptions. At the core of our study lies an important question: can SARs be integrated into Pakistani homes without disrupting cultural values, emotional connections, and religious beliefs? The findings provide an initial, nuanced perspective on this question, highlighting both opportunities and cultural concerns. In particular, they suggest that SARs could be more acceptable in Pakistani homes if their design were culturally and religiously sensitive and aligned with Pakistani traditions.

5.1 Opportunities for SARs

The reliance on traditional caregiving approaches in Pakistani households has long been shaped by combined family systems [8]. As these systems evolve and become more widely available, there are new opportunities for SARs to assist older adults in their home environments. However, our results show that it is essential for them to be aligned with the local culture, traditions, and religious beliefs.

5.1.1 From companions to needy robots with growing engagement and acceptance. Our findings highlight the important role of cultural norms and traditions in influencing how participants engaged with and accepted the robot within their daily lives. While both engagement and acceptance influence older adults' interactions with robots [32, 106], these interactions are heavily influenced by the older adults' perceptions of the robots [118]. Our findings from TAM 2 and the EAQ reinforce this, showing that perceptions, shaped by wider social and cultural contexts, are key determinants of both acceptance and engagement with robots. Rather than viewing SAR merely as a machine, participants in our study interpreted their interactions as involving an emotional bond. This was evident in instances where they referred to the robot as a "child" or engaged in extended conversations, often treating it as a good listener. This behaviour is in agreement with previous work (e.g., Spitale and Gunes [100]) on relational artifacts, which suggests that a consistent and responsive presence, even if delivered through robots, can fulfill emotional and social needs. This highlights how SARs could facilitate meaningful relationships through presence and responsiveness, which connects to more recent perspectives on designing robots that actively invite reciprocal care [52]. In this context, a theoretical framework proposed by Jones et al. [52] suggests designing "needy" SARs for older adults. In their work, "neediness" refers to carefully constrained behaviors such as requesting attention or small acts of assistance that can develop empathy, attachment, and engagement, rather than burdening the user. Our participants engaged with such behaviours towards the robot, and their comments suggested that similar behaviour on the robot's side would be welcomed. This suggests that, instead of completely automating household chores, we could use "needy" robots to help better integrate them within the Pakistani household, reshaping the distribution of care and support in daily life to enhance opportunities for SARs.

5.1.2 Recognising domestic workers in future care technologies. Our results highlighted the potential impact of the robot on domestic workers, who are rarely considered when designing SARs: while HCI research tends to focus on formal and informal caregivers, the perspectives of domestic workers remain largely unknown [39]. However, in Pakistani households, domestic workers hold a unique and often informal position within the caregiving ecosystem for older adults [20, 63], and therefore are a relevant stakeholder. Our participants mentioned their important role, emphasising the close bonds shared with them and the significant contributions they make to caregiving, which are also documented in the literature [45, 63]. Their role makes them valuable contributors to home care environments, even though they lack formal healthcare training. This role becomes especially important in hybrid care models that integrate assistive technologies, such as SARs. For example, Ribeiro et al. [85] proposes a hybrid care model that combines the healthcare management system with domestic care robots to support older adults. Building on this, in the Pakistani context, robots could be designed specifically to support domestic workers, facilitating their caregiving tasks [93]. As informal yet trusted individuals, domestic workers could help bridge the gap between older adults and technology, acting as a human connection to social robots [38].

Given the lack of evidence on whether domestic workers would embrace such technologies, we can only anticipate that, with an appropriate design for users with low literacy and limited digital familiarity, domestic workers could support older adults in interpreting reminders or interacting with robots. However, we believe that a successful implementation of this model would depend on three factors: (1) domestic workers' ability to engage with SARs, (2) cultural perceptions of their role within households, and (3) their willingness to participate in this process. Although domestic workers are often trusted, they are rarely empowered or seen as decision-makers [63]. Therefore, when designing technology for hybrid caregiving models, it is essential to consider not only usability and literacy, but also the social dynamics that define domestic workers' authority and treatment within households. Given their role in Pakistani households and our participants' expectations regarding the potential role of the robot in the home, this aligns with the augmentation model proposed by Stegner and Mutlu [104], which suggests that robots should enhance rather than replace human caregiving. Existing technologies show that this could be possible. For example, domestic assistant robots like Marvin [30] and augmented reality (AR) tools such as SHECS [116] show how robots and AR can support caregivers with physical tasks and information management. A similar approach could be developed to support domestic workers.

5.2 Design Considerations to Enhance User Engagement and Robot Acceptance

While prior research has primarily focused on how older adults in Western contexts perceive robots, both in controlled lab settings [28, 54] and in home environments [33, 40, 99], our work extends this research to non-Western settings, specifically Pakistan. Our findings from both qualitative and quantitative analysis reveal that perceptions, acceptability, and engagement with SARs are influenced by language, cultural values, and family structures. Importantly, these factors are not static; they evolve as users' circumstances change, such as through shifts in family dynamics or other life events. This highlights the necessity for SARs that can adapt dynamically to users' changing needs. Building on these insights, we propose six design considerations informed by our study. Figure 4 summarises the key points and presents them together with an illustration of a standard Pakistani household to highlight different stakeholders who may have to interact with or be affected by the robot. The proposed considerations could also be adapted to similar contexts in the Global South.

5.2.1 Fostering culturally embedded design. Our results highlight that designing SARs requires sensitivity to cultural and faith-based values, ensuring that technologies resonate with users' identities and practices. Therefore, we propose approaches such as faith-sensitive SARs and family-oriented customisation to better align technology with users' lived experiences.

(1) **Faith-sensitive SARs:** To achieve greater cultural and religious alignment, future SARs designed for Pakistani households should feature faith-sensitive conversational capabilities. This means integrating appropriate duas and maintaining verbal etiquette that aligns with Islamic interaction norms. Given that each individual's way of speaking, including their accents and dialects, varies [37], speech models need to be fine-tuned to reflect local dialects and religious vocabulary to ensure they resonate culturally. This could be achieved if developers curate a comprehensive, locally grounded glossary [59] that includes authentic conversational data from diverse regional dialects, everyday family interactions, and religious sources such as duas and Islamic media. This vocabulary must include common faith expressions (such as Insha'Allah, Mashallah, Alhamdulillah), contextual supplications for various life events, and culturally respectful honorifics. It should also capture phonetic variations and code-switching [26, 65] patterns among Urdu, English, and regional languages.

(2) **Family-centered customisation:** To enhance the use of SARs, we propose a family-centered customisation approach during the onboarding process. This would allow adult children to configure features for their parents, such as preferred greeting styles and religious expressions, reminders for medication or prayer times, shared libraries for photos and voice messages, and accessible activity schedules for the entire family. They could also set up multi-generational interaction modes, such as storytelling and educational games for grandchildren, Quran recitation sessions for elders, and prompts for shared mealtimes. Customisable conversation topics [80], memory prompts based on family events [117], and shared goal features (like step challenges or recipe exchanges) could encourage joint participation among family members [46]. By enabling adult children to tailor both the functional and social aspects of the robot, the SAR could become a bridge for cross-generational connections [115] rather than merely a personal gadget for older adults, which would make it more suitable for a Pakistani household.

5.2.2 Enhancing inclusive user access. Inclusive design must consider the various ways people interact with and derive meaning from technology. Therefore, we propose solutions that integrate rituals and offer adaptations for different literacy levels, broadening access while maintaining cultural relevance.

(3) **Rituals-integrated functionality:** Older adults living independently often forget to take their medications [29], and many may not be very tech-savvy [79] or know how to set alarms. Therefore, a robot could be designed for Pakistani Muslims that integrates medication schedules with daily prayer times. For example, reminders could be set to prompt users to "take medicine after Maghrib" (evening prayer). By using existing spiritual routines as natural reminders for medication, the robot could help reduce cognitive load for older adults [66] and develop medication routines [101, 103] while reinforcing their faith-based practices.

(4) **Suited for varying literacy levels:** Designing social robots for the Pakistani context requires careful consideration of literacy diversity [48]. Since literacy levels vary widely [95], robots should prioritise voice-first interactions in local languages. Additionally, they should include icon-based or touch-sensitive interfaces that minimise reliance on text for those who cannot read. As discussed above in Section 5.2.1, accommodating multi-user access is also essential in family and shared household settings. This approach would also allow domestic workers to engage effectively with the robot. This could be achieved by implementing features such as simple task dashboards with visual cues or shared verbal logs like "I reminded Mum to take her medicine," which can help coordinate caregiving responsibilities among family members and domestic workers. Previous research highlights that accessible multimodal interfaces enhance usability across various literacy levels [82]; thus, this design principle may

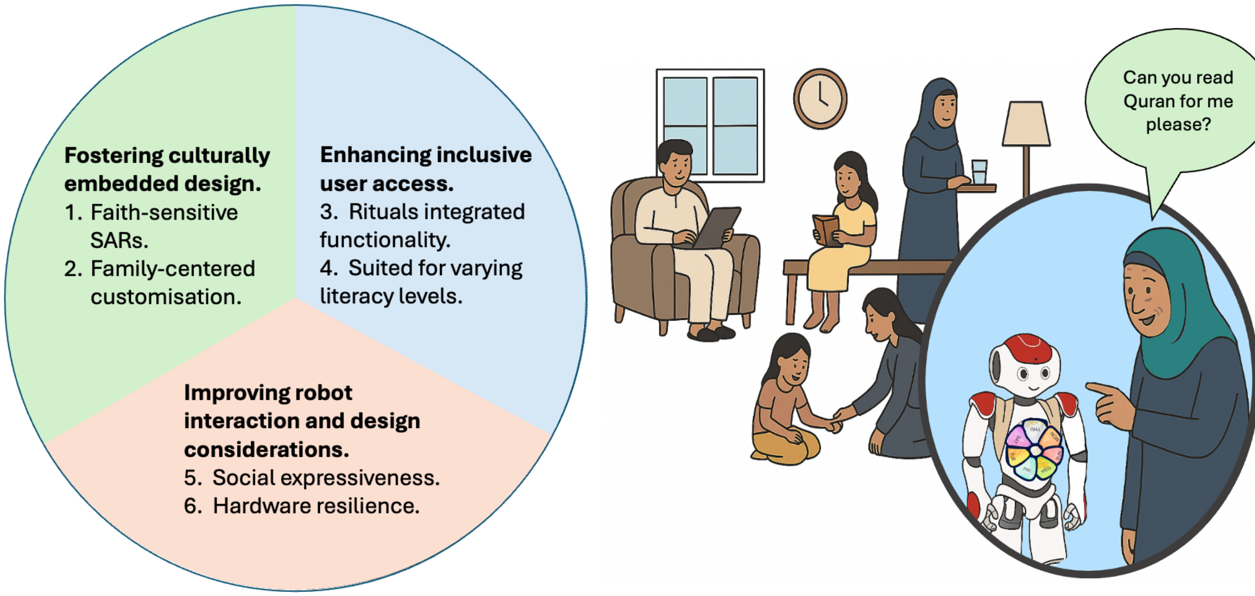

Figure 4: Design considerations for a culturally sensitive robot (described in detail in Section 5.2). The illustration on the right was co-created by the authors and ChatGPT-5, depicting a typical Pakistani household setting featuring a robot.

help ensure that robots' function as shared and accessible tool within the household.

5.2.3 Improving robot interaction and design. Effective robot design relies on both functionality and user interaction experience. We therefore emphasise factors such as social expressiveness and hardware resilience, which can enhance trust, usefulness, and user enjoyment.

(5) **Social expressiveness:** The robot must be socially expressive. It should recognise gestures, maintain appropriate eye contact, and turn toward users during conversations to enhance their presence and responsiveness. This is especially important in Pakistani homes, where non-verbal cues like eye contact, nodding, and body orientation are closely linked to respect and attentiveness, particularly toward elders [56], and our work confirmed that this had impact on our participants' attitudes towards the robot. By exhibiting these culturally valued behaviors, robots can build stronger relationships with older adults, helping them see robots as respectful companions rather than just machines.

(6) **Hardware resilience:** The hardware of these robots should be designed to suit local environmental conditions. They must incorporate passive thermal management systems and low-heat motors to cope with high ambient temperatures, as well as built-in power fallback options to handle load-shedding scenarios in Pakistan [19]. These design features would ensure that the robots remain functional, reliable, and safe even during the summer months and in the event of electricity outages in households.

5.3 Limitations and Future work

There are some limitations we would like to acknowledge. First, our study highlights users' first impressions but does not address how acceptance may evolve over time. However, this was an exploratory study that aimed to understand initial reactions to the robot by participants who never interacted with it in this particular setting. Furthermore, we managed to comprehend the shifts in perception by comparing the impressions on Day 1 and Day 3 of the study, similar to what Nientimp et al. [75] did in their research.

Second, the robot we used was not fully autonomous. Instead, we employed the WoZ technique to control the interactions. To some degree this has limited the responsiveness of the robot, e.g. resulting with comments that the robot was not able to answers at the moment when dealing with unexpected questions, as observed in other studies employing wizards [31, 86]. However, despite this limitation, this approach was appropriate for our study context. The WoZ setup ensured consistent and naturalistic interactions across participants, allowing perceptions to be shaped by the robot's social behavior rather than technical limitations. Moving forward, we aim to enhance the robot's autonomous speech capabilities for better user interaction.

Third, the way we presented the robot with accessories may have influenced participants' perceptions. Although none of the participants commented on robots' clothes and the medication box, its presence might have drawn their attention to it, influencing their experience. Furthermore, the prominent placement of the medication box introduces a risk of unintentionally reducing older adults to their medical needs. While we did not observe this effect in our study, future research could examine how different types of robots and accessories shape people's perceptions and expectations in different contexts.

Fourth, since all participants in our study were educated, their perceptions of the robot may have been influenced by their educational background (see Table 1). Future research could explore how individuals with lower levels of education or literacy perceive and interact with the robot.

Finally, the research was conducted in participants' home environments, where distractions such as kitchen activities or phone calls occasionally interrupted the sessions. While we asked participants to pause household tasks during the interactions, some interruptions were unavoidable. This was a potential limitation, as it could have briefly disrupted participants' focus on the robot. However, these distractions also contributed to a more naturalistic setting, since such interruptions and background noise are an inevitable part of everyday home life and thus reflective of the context in which the robot would ultimately be used.

6 Conclusion

This study highlights how older adults in Pakistan perceive and interact with social robots in their homes, particularly in the context of aging and cultural expectations. Our research involved 14 older adult participants who saw robot speaking Urdu as a potential member of their households, who could recognise religious values, assist with daily tasks, provide timely reminders, and most importantly, offer companionship. The findings highlighted the need for an important social transformation: reimagining caregiving and companionship through technology, influenced by evolving family structures and cultural values. We argue that social robots, when designed with an understanding of these dynamics, have the potential to become trusted and integrated parts of older adults' everyday lives. The design considerations we propose are aimed at creating social robots that respect cultural norms, foster meaningful companionship, and adapt to the daily practices, health needs, and values of older Pakistani adults and similar contexts.

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