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Understanding the Impact of Robots' Embodiment on User Acceptance and Engagement: Perspectives of Older Adults from Pakistan

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Abstract
With Global South's (GS) aging population and advancements in technology, social robots have emerged as a potential alternative for supporting elderly care. However, there is a limited research investigating the engagement and acceptance of technology in GS. This paper investigates the engagement with and acceptance of three differently embodied social robots (Vector, Miro, Nao) among older adults in Pakistan. Through mixed methods, including interviews, questionnaires and interactions with the robots, this study explored the perspectives of 14 Pakistani older adults, including their thoughts on potential use of robots in home settings. Our findings highlight concerns that need to be addressed for a successful deployment of social robots in Pakistani context: existing cultural differences, older adult's technological literacy, and language barriers. Participants preferred a human-like Nao robot because it was perceived as more reliable and familiar, partly due to exposure to robots in the media. Based on these results, we propose design considerations for deploying social robots in Pakistani home settings.

Keywords Global south · Social robots · Older adults · Pakistan · Culture · Home settings

1 Introduction

Two thirds of the world-wide older adults population reside in the Global South (GS) [1]. Globally, the older adult population has been experiencing significant growth [2], and this trend is expected to continue growing in the future [1]. As an example, Pakistan has an ageing population of 15 million and it is expected to increase to 40 million by 2050 [3]. The older adults in the GS experience several challenges such as heightened poverty, limited access to services, and compromised physical safety [4]. In addition, several studies focused on the GS emphasise the need for senior care facilities [5] to address a wide range of issues, including: growing population of older adults [6], increased demand for healthcare systems [7], housing requirements [8], increasing loneliness [9], cases of children abandoning their parents [10], and a rise in cases of abuse [11] and neglect of older adults in home settings.

Traditionally, in the GS and particularly in South Asia, children are encouraged to live with and care for their elderly parents as part of a traditional norm of filial piety [12, 13]. However, there is evidence that filial piety is undergoing changes and children are migrating to other countries for better opportunities [14], leaving their parents living alone [7, 11, 15]. In response to this shift, various technological solutions such as remote health monitoring [16] and telemedicine [17] have shown promise in addressing the challenges faced by older adults living alone. In the Global North (GN), a wider range of similar technological solutions is available, including robots, smart home systems, chatbots, or voice assistants [18–20]. Technology creates

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opportunities to develop innovative solutions for older adults in South Asia and the GS more broadly to support them with independent living and managing their health care needs. However, despite the emerging situation, such technology is currently under-utilised in the GS, mostly due to low digital literacy [21] and high costs [22], and consequently facing acceptance challenges among older adults [23].

Given that the older adults in GS are fac-ing several challenges and technologies such as robots have a potential to support older adults in their daily living [24], our aim was to explore the potential use of social robots to support older adults in GS, with Pakistan as a case study. To this end, we conducted a study with 14 older adults to investigate their level of acceptance and engagement with three differently embodied social robots. Through a mixed methods study, we investigated older adults' preferences and attitudes regarding the potential use of social robots in their home settings.

Our work makes several contribution. First, to the best of our knowledge, this is the first study to explore the attitudes of older adults in Pakistan, towards social robots. Second, we provide a better understanding of older adults’ perspectives and expectations related to potential utility of robots in their homes. Third, our work provides design considerations and suggestions on what researchers need to keep in mind when deploying robots in Pakistani home settings. In particular, we highlight the importance of adopting family-centered approaches in design, the need to consider cultural preferences such as size, shape, and embodiment in robot design, and the need to address language barriers and consider different accents and local dialects.

2 Background

2.1 Social Robots and Older Adults: Opportunities and Socio-Cultural Challenges

Recent years have seen an increase in the use of emerging technologies to support older adults, for example, robots that provide information, companionship, and emotional and mental support [25, 26]. Specifically, social robots (defined as “embedded systems designed to interact with humans” [27]) have witnessed wider applications in domains such as healthcare, education, and public spaces in different parts of the world, especially in the GN [28–30]. Current work has shown the benefits of utilising social robots in several other ways within the home environments, including: providing medication reminders [31], managing older adults’ day-to-day routines [32], supporting long-term social interactions to keep them engaged, e.g playing music [33], or discussing news to overcome boredom and loneliness [34]. Furthermore, social robots have also been used in reducing and managing depression [35, 36] and providing health care support [37]. However, this large body of research has been conducted using social robots to support older adults in various ways in the GN. Even though some studies explored the use of robots in the GS (e.g. [38, 39]), there are no studies focused on older adults’ perspectives and expectations of using social robots in the home settings.

To effectively implement social robots at home in any socio-cultural settings, it is important that older adults not only accept these robots but also actively engage with them [40]. Previously, the CARESSES project investigated the expectations of older adults towards robots in different cultures, focusing on Japan and United Kingdom [41]. The researchers suggested that the initial acceptance of social robots should be aimed at assisting older adults in their daily routines in accordance with their cultural settings, including medication reminders, addressing boredom by engaging in conversations about their habits, local news, and maintaining up-to-date health data in accordance with local systems [41]. However, as socio-cultural settings and preferences in the GS are different from those in the GN [42], user acceptance and engagement towards robots may differ as well.

2.2 Engagement with Social Robots

Engagement can be defined as a collaborative process and a reflection of user involvement and interaction [43]. While the gaze, eye contact, gestures and facial expressions are the non-verbal ways of engaging with the robots [44–46] Sidner and Dzikovska [47] suggest that engagement can occur without gestures and face-to-dace interactions, e.g. in phone call conversations, engagement is about building a connection and having a meaningful conversation. Gestures and facial expressions are the other forms of communication that drive engagement [45]. This is why social robots have been designed for more expressive conversations using gestures, facial expressions, verbal responses, and gaze. For example, the Pepper robot provides efficient natural interaction to achieve a high level of human-robot engagement [48]. In the context of robots, engagement has been studied to understand how robots can interact more effectively with humans. For example, in education scenario, such as a museum [49] and educational settings i.e., schools [50], the ability to engage users is important. It is widely known that a higher level of engagement leads to better learning outcomes [51]. However, in different settings where the primary intention is not learning but rather keeping users away from feeling loneliness, engagement takes on a different dimension. For example, [34] explored the potential of social robots to act as companions for people who experience isolation. Through engaging individuals in meaningful conversations and addressing their emotional needs, the robots have the ability to create a sense of companionship and a better engagement with the users [34]. Research shows that users' engagement plays a significant role in promoting the acceptance [52].

2.3 Acceptance of Social Robots

User acceptance is defined as "the demonstrable willingness of a user group to employ technology for the tasks it is designed to support" [53]. It is a critical factor for the successful integration of robots in the lives of older adults. However, acceptance may change over time [54], often due to a novelty effect [55], as it is a multifaceted phenomenon, influenced by a range of factors including individual preferences, technological familiarity, cognitive abilities, and cultural background [56]. In addition, While some older adults may embrace and accept robots as valuable companions or assistants, others may exhibit skeptical or reluctant behavior [57].

Many studies conducted in the GN show the acceptability of the robots in home settings (e.g. [58, 59]) although they suggest that the acceptance can be mixed and vary significantly, depending on robots' functionality and geographical location [60]. Furthermore, Gates [61] identified that robots can be seen as acceptable for people in their daily living, but they also uncovered some limitations. For example, they showed that the fact that robots cannot improvise – they only do what they are told to do – reduced acceptance. Finally, financial aspects, such as the initial cost, may also cause difficulties and hinder acceptance of robots for many people [62]. These limitations highlight the complex nature of acceptability of robots in home environments, leading to the exploration of how specific robots' appearances, i.e., embodiment, can influence user attitudes towards robots.

2.4 The Impact of Embodiment on Attitudes Towards Robots

Embodiment (i.e., physical presence) is a critical factor influencing Human-Robot Interaction (HRI) [63] because the physical form and appearance of a robot have a significant impact on how humans perceive and interact with it [64]. Based on work by Dautenhahn [65], we define robot embodiment as "the existence of an agent (in this case, social robots) within a physical body and appearance that can observe social cues, possess a persona, and utilise its physical form to interact with users in a social context." Embodiment also refers to the capacity to perceive the robot as having embodied intentionality; it involves more than just seeing it with human-like characteristics [66, 67]. Furthermore, effective embodiment in HRI must include natural interaction patterns, adaptive behavior, and intentional expressiveness—elements that extend beyond just physical form [68].

To understand the impact of embodiment, [69] examined how people interact with different kinds of Voice-User Interfaces (VUI), including social robots and smart speakers during a 4-week deployment at home [69]. They found that users engaged with a social robot (Jibo) more than with smart speakers (Amazon Echo & Google Home) because of the social nature of interactions with the robot and its physical appearance. Moreover, the research with differently embodied social robots shows that embodiment affects users' engagement and trust. For example, Natarajan and Gombolay [70] studied the impact of user's perceived anthropomorphism of robots on trust. They used four robots (Pepper, Nao, Kuri and Sawyer) to observe whether humans would rely on a robot to make decisions under pressure. Their results show that behaviour and embodiment of the agent were the most significant factors in predicting the trust and engagement with the robot. They also observed that the interactions between different robot types could be significantly different depending on how quickly and effectively the robot responded to its users [70].

Research also shows that older adults prefer to interact with robots that have more social and physical embodiment, including size, appearance, and other human-like features, as well as social skills [71]. Furthermore, [64] suggest that robots that display warm and friendly body language are more likely to be perceived as more trustworthy. However, it is important to note that users' perceptions may vary when interacting with robots of different physical embodiment [72]. As a result, these perceptions can assist users in interacting differently and more efficiently with social robots [70]. All of this shows the significant impact that a social robot's embodiment has on the user engagement and acceptance of social robots. However, we know very little about perceptions and preferences of users from the GS.

In sum, previous research has highlighted the factors that can affect the attitudes and acceptance of social robots among older adults [58]. However, there is a notable gap in terms of research on the use of social robots with older adults in GS, as well as a lack of clear design recommendations for deploying robots in older adults' homes in the GS context. Therefore, our study aimed to explore the opportunities and challenges of using social robots with older adults in Pakistan, and to gather knowledge on their preferences, attitudes, and concerns when presented with different robots, each of which has different types of interactions.

3 Method

3.1 Research Context

3.1.1 Site Selection

The study was conducted in Lahore city district. The city is the second largest in Pakistan with the population of over 7 million people [73] and also serves as the capital of the Punjab Province. The rationale behind selecting an urban city for this study lies in the increasing prevalence of the nuclear family system in urban areas [74]. In such areas, there are many older adults whose children reside abroad for reasons such as education, employment, or other commitments [75], leading them to live independently [76].

3.1.2 Researcher Positionality

Two of the authors are from Pakistan, but have lived abroad for 9+ years. They are both insiders to Pakistani culture and outsiders due to their current geographic location. Moreover, one of them lives in the UK while his parents live independently in Pakistan. Their experiences enabled deeper insights into local systems, and helped us communicate with the participants and conduct parts of the study in their local language (Urdu). The other team members are interdisciplinary researchers with diverse backgrounds, with many years of experience working in the GS, including South Africa, Ecuador, Peru, Mexico, Chile, India and Bangladesh. The whole team's prior experiences played a pivotal role in shaping the overall study and influenced the interpretation of its results.

3.2 Participants and Recruitment

As the life expectancy in Pakistan is 66 years old [77], we decided to recruit participants aged 50 or over. We selected a broad age range for our participants for two main reasons. First, we aimed to capture the perspectives of different generations (older adults and adults aged 50 and above who have older parents), as they possess varying skills and levels of literacy when it comes to using robots. Second, the retirement age in Pakistan is 60, so we wanted to include both retired adults and those approaching retirement. As a result, we recruited 14 adults (9 men, 5 women) aged between 50 and 82 (average = 59.8, SD = 9.40; see Table 4 in the Appendix) who had no prior experience interacting with robots as they are uncommon in Pakistan [78]. Participants were recruited by a local university, where the study was conducted, through convenience sampling [79], and by advertising the study on their social media platforms and within the university premises.

Our inclusion criteria required participants to be fluent in English, educated, and free from any serious health problems that might hinder their ability to participate in the study, such as significant physical issues. We excluded individuals who did not meet these criteria. Moreover, all participants were either currently employed at various educational institutions in Pakistan or had retired from such institutions. This ensured that their skills and literacy levels were comparable. As a token of appreciation, each participant received a pack of confectionery items. The study received a favourable ethical opinion from the review board at the local university in Lahore that was responsible for participant recruitment.

3.3 Study Design

The study followed a within subjects design where each participant interacted with all three robots, which allowed us to compare the responses and behaviors of the same participant under different conditions [80]. We randomised the order of the robots to minimize its potential influence on participants' behaviors. Additionally, we attempted to introduce randomness into the interactions with the robots by employing a dice-rolling method during activities (see Sect. 3.4.4). Finally, as previous research suggests that acceptance and engagement can be measured in short-term interactions [40, 69, 81], we conducted the study in a single interaction session to capture participants' initial reactions. The study was conducted in English as the robots could not speak Urdu; however, participants had an option to respond in Urdu during the final interviews if they wanted to.

3.4 Materials

3.4.1 Robots

We used the three social robots shown in Fig. 1. We selected these specific robots because they have different sizes, have the capability to respond to their users, have different embodiment features and offer different types of interactions:

- **Vector:** It is a toy-like home robot, mainly used as a companion to help, hang out, and play games [82] (see Fig. 1a). It is a rather small robot (13.33 ×10.16 ×20.32 cm) and can be easily placed anywhere. It has a voice interface and can respond to commands.
- **Miro:** It is a fully programmable autonomous robot [83] for researchers, educators, developers and healthcare professionals. It is small (36 ×34 cm), although bigger than Vector, and has a friendly pet-like appearance and qualities (see Fig. 1b). It has a wide range of capabilities, including movement and communication.

(a) Vector (b) Miro (c) Nao

Fig. 1 Robots that represent varying levels of embodiment and different sizes.(**a**) vector (**b**) miro (**c**) nao

- **Nao:** Nao is a medium-sized (57.4 ×27.4 ×30.9 cm) humanoid robot from Softbank Robotics [84]. It has many capabilities e.g., performing the complex gestures with its hands, head and upper torso (see Fig. 1c).

3.4.2 Movement Setup and Speech

To allow for a better control during the study, we limited the random body movements of the Vector robot after finding that it could be distracting to users in our pilot study (Sect. 3.7). We also used the MiroAPP to control Miro's gestures such as nodding, blinking, and wagging its tail when interacting with humans, and restricted some of Nao's abilities, such as responding to random questions.

We employed a Wizard of Oz (WoZ) [85, 86] control for the speech of all three robots, as opposed to relying on the robots' own speech and language understanding, given that the latter is less efficient and occasionally ineffective [87]. WoZ technique is primarily used for simple hypothesis testing [88], especially in the early stages of research. Developing fully autonomous robots is complex and time-consuming, which is why WoZ allows researchers to test concepts and evaluate user responses without needing a complete system and realistic user interactions [86, 89]. We used a tool called TKinter which is a standard Graphic User Interface (GUI) library for Python that enables a faster way to create GUI applications. We created a GUI interface with the buttons that corresponded to each activity on the activity sheet (see Sect. 3.4.4). As some activities involved a two-way conversation between the robot and the participant, we created multiple buttons for each robot response and added a text box to ensure that the robot could respond to any unexpected comments from the participants (see Supplementary Information).

3.4.3 Questionnaires

We used two questionnaires to evaluate the interactions. We used Technology Acceptance Model 2 (TAM 2) questionnaire [90–92] to assess the participants' willingness to use robots for specific tasks. Our objective was to determine which types of robots the participants were open to interacting with from the options provided. Based on previous literature [93], we were primarily interested in two parameters to measure acceptance: perceived ease of use and perceived usefulness. These two parameters are further sub categorised [91] into perceived enjoyment, perceived usefulness, perceived ease of use, perceived adaptability, and anxiety. Questions were adapted according to all these 5 categories (see Supplementary Information) and used with a 5-point Likert scale.

We also created a ranking questionnaire that enabled participants to rank the robots according to their experience of interaction, robots' appearance and robots' voice. For each aspect, participants were presented with pictures of all three robots and asked to rank them accordingly. The primary objective was to investigate whether these factors, namely the robots' appearance and voice, influenced participants' preferences when choosing their preferred robot. The ranking questionnaire is available in the Supplementary Information.

3.4.4 Activity Sheet

To ensure the diversity of interactions, we designed an activity sheet with a list of 26 activities (see Supplementary Information). A large number of activities were selected to ensure that participants have a chance to interact with each robot as many times as possible to provide sufficient interaction data for the analysis. It included a wide range of in-home tasks inspired by the previous literature (e.g. [71]), including informative (news, weather), entertaining (music, dance, jokes) or mutual tasks (robot asking questions about participants' personalities and the possibility of having a robot at their home, participant asking questions about robots personality or asking one robot about the other robot's personality).

The activity sheet was accompanied by a 20-sided die and a 6-sided die to allow selection of the 26 activities from the list. We decided to use the dice, rather than planning in advance the order of activities or automatically randomising them during the sessions, because it introduced an element of unpredictability and helped to ensure that each participant's experience was unique. Every time participants rolled the dice, they had to add both numbers and choose the corresponding activity on the sheet. For example, if a participant rolled 14 and 2, they had to find the activity number 16. If a participant rolled the same number more than once, they were asked to either roll the dice again or to chose any activity that has not been previously selected.

3.5 Study Setup

We conducted our study in a lab space that included a table and a chair. The robots were placed on the table in random order for every participant. For each session, the placement order of the robots on the table was determined by a random selection process. Given the height, Nao was placed in the sitting position on the table to be at the participants' eye level. Two video recording cameras were used: Camera 1 (C1) with a tripod was placed at a side to capture all robots and the participant, and Camera 2 (C2), a desk camera placed on the table, was used to record participant's face (see Fig. 2). The activity sheet was also placed on the table. Two researchers (R1 and R2) were sat on the other side of the table where they controlled the robots.

3.6 Procedures

The research was conducted in November and December 2022. Prior to the study, participants were asked to complete an online pre-study questionnaire/sign-up form to confirm their eligibility and gather demographic information (e.g., age, English language understanding, gender; see Table 4 in the Appendix). We also provided participants with an information sheet and a consent form before their participation, including consent to video and audio recording.

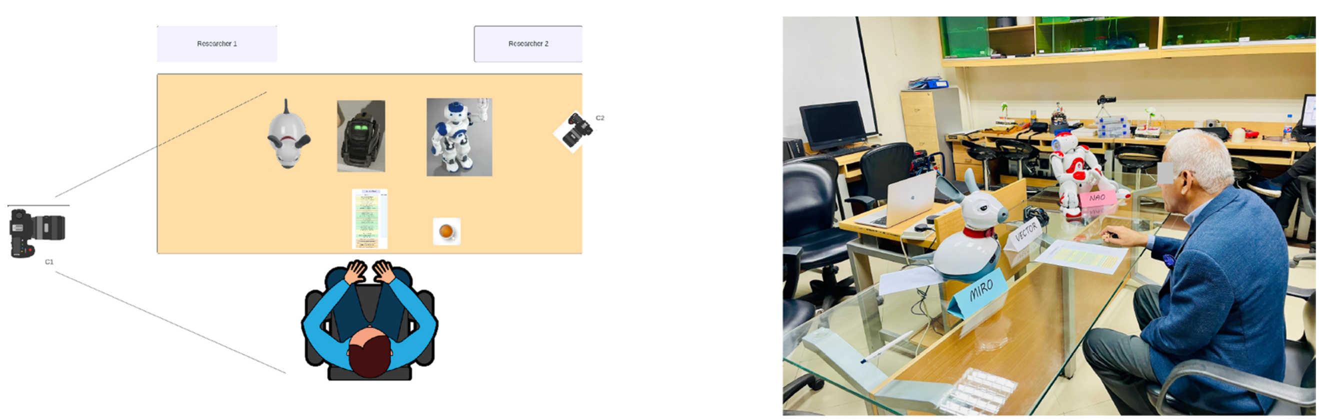
Each session was conducted by two researchers (R1 & R2). R1 facilitated the session, controlled the speech of Vector and Miro through WoZ, and interviewed the participants at the end. R2 controlled the speech of Nao through WoZ. The study was performed individually, one participant at a time, and lasted approx. 60 minutes per participant.

The study began with an brief introduction and an overview of the robots. Following this, we provided a general overview of the session, including the overview and timings of the main parts. The session had three parts: 1) participants interacted with robots for 20–25 minutes using the activity sheet to familiarise themselves with the robots; 2) participants were asked to complete the two questionnaires; and 3) participants were interviewed at the end of the session.

3.6.1 Interactions with the Robots

The first part of the study started with robots introducing themselves; this part was scripted and always followed the same order. The robots talked in English with occasional Arabic words used as greetings. First, Vector introduced itself, asked participants their name and presented other robots:

Assalam Alaikum, I am Vector and my friends are Miro and Nao. What is your name?



(a) (b)

Fig. 2 Study setup: **a**) the top-view showing the placement of the robots and position of the participant and researchers, **b**) a photo of a participant interacting with the robots during the study

Next, Miro explained the activity sheet:

> *"Salam. We are pleased to meet you*<<PARTICIPANT NAME>>,*please have a look at the activity sheet. [pause]*
>
> *There are 26 activities here and you have two dice. Some activities involve the robot speaking more, while in others, you are expected to speak and respond to the robot."}*

Finally, Nao explained the session and how rolling dice activity would work in more detail:

> *"Assalam Alaikum. You need to roll the dice and perform the corresponding activity with any one of us. Please ask the researcher if you have questions [pause]*
>
> Let's start."

Then, participants were asked to roll the dice to select activities from the list. After selecting each activity, participants were asked to choose the robot to perform it with. This part of the study lasted approximately 15 minutes and participants had to perform as many activities as possible during this time.

Next, one robot asked participants about the ways in which robots could potentially be beneficial in home environments (the last five questions from the activity sheet; see Supplementary Information). The robot for this task was selected by the researchers, taking into consideration whether the participant had interacted (or not) with it during the activities and to counterbalance any preference they might have had towards specific robots. For example, if the participant predominately chose Nao or Vector during the activities, the final questions were asked by Miro. The robot asked questions for 5–10 minutes.

3.6.2 Questionnaires

Next, participants were asked to complete the TAM 2 and the ranking questionnaires. R1 briefly discussed the ranking questionnaire responses with the participants, which allowed us to explore the reasons behind their choices when ranking the robots and to understand how the robots could have performed better during the interactions. This part took approximately 5–10 minutes.

3.6.3 Final Interview

Lastly, each participant was interviewed by R1. Interviews covered two main aspects. First, they discussed the overall interaction experience with the robots including questions about participants' preferences regarding the robots' voice and appearance and why they preferred a particular robot. Second, participants were asked about the feasibility of having robots in their homes. Questions revolved around their preferred robot for home use, where participants would place the robot, potential challenges the use of the robot might face at home, how the robot could assist in medication management if they take any, and other scenarios where they could think of the robot being helpful in a home setting. Participants were also asked to provide their opinions and suggestions for the robots. The interview questions can be found in the Supplementary Information.

3.7 Pilot Study

We conducted a pilot study with two researchers to test the robot, room setup and procedures, and to identify potential issues. Based on these sessions we made some changes. First, we found that Vector's default random movements were distracting, including the robot falling down the table at one point; as a result we had to disable them. In contrast, Miro was generally static which was perceived as not engaging, so we added extra movements such as blinking eyes, nodding and wagging tail. We also adjusted the timings, improved the study introduction to make sure both the robots and the procedures are clearly described, and fixed typos in the questionnaires.

3.8 Data Analysis

We analysed three types of data: interaction video recordings, questionnaire responses and individual interview transcripts. For anonymisation, participants were assigned IDs from P1–P14.

3.8.1 Video Analysis

The overall camera view (C2) was used for the analysis. The participants' behaviors were categorised into two main types: verbal interactions (such as speech and conversation) and non-verbal interactions (including gaze facing the robot, facial expressions, and gestures expressed in response to robot action) based on prior research guidelines outlined by [94] and applied by [38, 95]. We also analysed participants' interaction time with each robot.

R1 coded the video data using a coding software ELAN [96] and R2 and another co-author confirmed the codes generated by R1. The coding was further discussed with the other co-authors. For the coding purpose, we carefully annotated the aspects that changed visually (i.e., gaze, gestures, facial expressions) during each interaction and we also measured participants' verbal responses aimed at robots.

All the annotations (gaze, verbal response, facial expressions and gestures) for each robot were further normalised [97] to allow fair and meaningful comparison of participant responses across different robots and activities [97]. Building upon the normalisation process, an Analysis of Variance (ANOVA) [98], was used to investigate whether there were statistically significant differences in the normalised data among the three robots (Vector, Miro, Nao) and the various behavioral variables (verbal responses, facial expressions, and gestures).

3.8.2 Questionnaire Analysis

To analyse TAM 2 results, we followed a systematic process for the questionnaire analysis, which involved several steps. Initially, we 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. Following this, we calculated Cronbach's Alpha variable [99] for each parameter as well as for the overall data, which helped us process the reliability of the acceptability questionnaire. We first calculated the scores of each parameter and calculated Cronbach's Alpha value for each acceptability parameter. A Cronbach's Alpha value of at least 0.7 is considered reliable. In our data, the Cronbach's Alpha value was 0.695 (0.7 round off) for the overall scores; individual Cronbach's Alpha values are as shown in Table 5 in the Appendix. All values show the reliability of data, only anxiety had a lower alpha value compared to others. Following this, we conducted an analysis of basic descriptive statistics, which included determining the minimum, maximum, mean scores, and the standard deviation. They provided an initial understanding of our data based on score distributions. Lastly, we computed correlations between each acceptability parameter to explore if there were any significant relationships between these parameters. This step helped us uncover potential patterns or connections in the data [91].

To analyse the ranking questionnaire, a chi-square test of independence was used to identify associations between the robot type and the key parameters (user experience, appearance, and voice).

3.8.3 Interview Analysis

As all participants decided to respond to the interview questions in Urdu, the interview recordings were transcribed in Urdu and subsequently translated into English by R1 (the first author) to enable discussions with the other team members. Given that both R1 and R2 are bilingual, the transcriptions underwent a cross-checking process by R2 to ensure accuracy and consistency in the translation.

The interviews were analysed thematically using an approach based on framework analysis [100]. This method employs an organised structure that is suitable for top-down analysis and were were interested in specific questions; we followed the same approach as reported by [101]. After familiarization with the data, the transcripts were summarised in a framework table, where each row corresponded to an individual participant, and each column represented responses to different interview questions. This tabular format facilitated easy comparison and contrasting of data across participants and questions, enabling the identification of key trends and codes. These trends were then discussed with rest of the research team, resulting in a set of initial themes (robots' looks, robots' tasks, constant comparisons of robot with human beings, cultural barriers and language understanding barriers). Finally, the links and common trends were identified based on the completed table and discussed with the team members to finalise the main themes that were then linked with the key aspects we were interested in: embodiment, engagement and acceptance.

4 Results

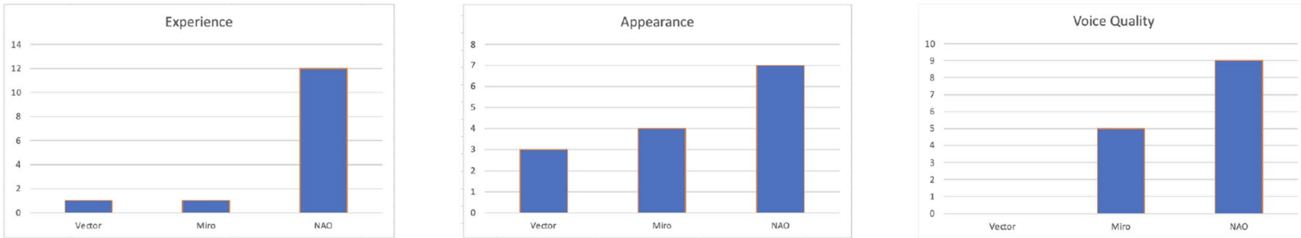
Given the aims of the study, we present the combined quantitative and qualitative findings organised around the wider topics of embodiment, engagement and acceptance of social robots.

4.1 Embodiment: Users' Preferences and Robots' Appearance

4.1.1 Ranking Results

Participants ranked their experience of interacting with the robots, robots' appearance, and their voice. In terms of **interactions** (see Fig. 3), Nao was ranked the highest by 12 participants, while Miro and Vector were ranked as the best by only one participant each. A chi-square test of independence for frequency analysis was performed to examine the relation between robot type and interaction with the robot; the relation was statistically significant, $\chi^2(1, N = 13) = 17.33$, p=0.0002, suggesting that Nao robot was ranked significantly higher in terms of interaction experience as compared to Miro and Vector.

In terms of **robots' appearance** (see Fig. 3b), we found that seven participants ranked Nao as their first choice, while four participants chose Miro and three participants chose



(a) Ranking according to Interaction experience

(b) Ranking according to Robots' appearance

(c) Ranking according to Robot's voice

Fig. 3 Participants' preferences for the nao, vector and Miro robot in terms of interaction experience, appearance and voice.(**a**)ranking according to interaction experience(**b**)ranking according to robots' appearance (**c**) Ranking according to Robot's voice

Vector. A chi-square test of independence for frequency analysis was performed to examine the relation between robot type and appearance of the robot. The relation between these variables was not significant ($\chi^2(1, N = 13) = 1.868$, p=0.39), suggesting that participant did not rate any robot's appearance significantly higher in comparison with each other.

Lastly, with regards to the **voice** (see Fig. 33C), we found that participants preferred Nao as 9 of them ranked it first, Miro came in second with 5 participants choosing it as their first choice, and Vector was not chosen by any participants as their first choice, possibly due to its mechanic voice and some lags in the response (described further in Limitations). A chi-square test of independence was performed to examine the relation between robot type and robot voice. The relation between these variables was significant ($\chi^2(1, N = 13) = 8.73$, p = 0.0127), suggesting that Nao robot was ranked significantly higher as compared to Miro and Vector.

4.1.2 Participants' Perception of the Appearance and Functionality of the Robots

When we asked participants to compare the three robots, we noticed that participants' choices were based on the robots' appearance and the tasks they expected the robots to perform. In particular, participants emphasised that the perceived capabilities of each robot played an important role in their preferences. For example, Vector's size suggested it could fit anywhere and Nao's hands implied the ability to grab or point towards the objects.

While participants liked all three robots, they were seeking a robot without physical limitations to assist with tasks such as fetching water from the kitchen. Furthermore, they desired a robot that could handle various household chores like dish washing, vegetable cutting, or other food preparations. In terms of physical capabilities, the participants perceived Nao as the most purposeful robot, capable of handling a variety of tasks.

> *"I will prefer Nao because its features are more like humans. It can be good for talking, and help me with different tasks because of its physical capabilities".* (P6, Woman, 50)

At the same time, eight participants expressed concerns about the perceived limitations of Vector and Miro robot:

> *"Vector and Miro looks like limited use for me. They can point to the things but not much. While I think Nao can do many more things".* (P8, Man, 62)

Moreover, all participants acknowledged having a preconceived image of humanoid robots, envisioning them as beings with human-like characteristics. Consequently, when exposed to three differently embodied robots, they faced difficulty perceiving Miro and Vector as "robots":

> *"Miro looks quite weird* [like a mix] *between panda, kangaroo, rabbit or cat. But it is just pathetically weird. Nao I know, I have seen it in a picture before and it speaks very clearly like a human and I can see that it follows me wherever I move. Vector is cute because it reminds me of different cartoon characters not a robot".* (P9, Man, 50)

Participants also emphasised the significance of robots' size, especially in regions like under-developed countries such as Pakistan. They thought that the introduction of robots might evoke an intimidating response from the local population, as most people are not familiar with robots. They urged careful consideration in deploying robots, given the limited familiarity people may have with such technology:

> *"You need to make sure that people don't get scared when they see the robot at night. I think a lay person might be scared of the robot anyway".* (P3, Man, 59)

Table 1 Annotations of each category in msec

Robot	Each interaction duration (msec)	Gaze duration (msec)	Verbal duration (msec)	Expression duration (msec)	Gesture duration (msec)
	(Mean, SD)	(Mean, SD)	(Mean, SD)	(Mean, SD)	(Mean, SD) Salam. We are pleased to meet you
Nao	0.39679713, 0.118452664	0.4527400, 0.18871914	0.2485840, 0.12483622	0.0894617, 0.11389714	0.0104308, 0.01308021
Miro	0.33142559, 0.096575161	0.4407638, 0.13652667	0.2395380, 0.14390620	0.1060299, 0.14531912	0.0087503, 0.01467865
Vector	0.27177729, 0.137582683	0.4910447, 0.23300054	0.2428754, 0.23680463	0.0518759, 0.10974799	0.0119406, 0.01700695

4.2 Engagement: Interaction with the Robots

4.2.1 Engagement Results Based on Verbal and Non-Verbal Responses to Robot

In this section, we present the findings based on the verbal and non-verbal behaviours recorded during the video analysis. We considered gaze towards the robot, gestures, and facial expression duration as non-verbal behaviours, and spoken responses as verbal behaviours [47]. Our findings showed that on average participants spent around 24.52 minutes completing the interactions with the robots. Overall, 175 interactions were coded with an average of 12.5 interactions per participant, with an average length of 1.96 minutes per activity. Moreover, between 175 total interactions, participants interacted 69 times with Nao, 58 times with Miro and 48 times with Vector.

To investigate the difference in engagement with the three robots, we conducted an analysis of variance (ANOVA) with participant's interaction duration (length of interaction time with each robot), gaze duration towards the robot, verbal response duration, gesture duration and facial expression duration as dependent variables and type of robot as independent variable. We found a statistically significant difference in the interaction duration (amount of time participants spent) with each type of robot ($F(2,39)=3.88$, $p<0.05$). However, we did not see significant difference for the duration of participant gaze facing the robot ($F(2,39)=0.267$, $p=0.76$), verbal response ($F(2,39)=0.01$, $p=0.991$), facial expressions ($F(2,39)=0.701$, $p=0.502$), and gesture ($F(2,39)=0.158$, $p=0.854$).

Further analysis was conducted to compare the duration of interaction for Vector, Miro, and Nao. A Bonferroni posthoc test showed that Nao interaction duration was significantly higher than Vector ($p<0.05$). No other significant differences were observed. The mean and standard deviation of each annotated parameter can be found in Table 1. These results indicate that there were no significant differences in participants' non-verbal behaviors across different robots. However, the level of engagement, as measured by the duration of interaction with each robot, varied significantly. This suggests that participants showed a preference for engaging more with one type of robot over the others. In this case the preferred choice was Nao, followed by Miro and Vector. When looking at the data according to the time duration, the way in which participants interacted (non-verbally) did not differ: all of the participants engaged in the similar manner showing similar gaze, facial expressions and gesture behaviour with each of the robot.

Table 2 Total number of annotation in each category for engagement

Interaction Type	Vector N (%)	Miro N (%)	Nao N (%)	Total annotations N (%)
Gaze	110 (26.38%)	142 (34.05%)	165 (39.57%)	417 (100%)
Facial Expressions	16 (17.39%)	34 (36.95%)	42 (45.65%)	57 (100%)
Verbal Response	135 (26.46%)	162 (31.51%)	216 (42.02%)	514 (100%)
Gestures	23 (40.35%)	12 (21.05%)	22 (38.59%)	92 (100%)

We also counted all annotated categories for each robot (see Table 2). We annotated a total of 417 items in the gaze category when the participant was looking at the robot during the interaction; 165 annotations were made for Nao robot, accounting for 39.57% of all recorded gaze interactions. Further, we annotated a total of 92 facial expressions that were mostly a smile and in one case a confused expression when a participant could not understand the robot. We also annotated total 514 verbal responses that included the chat with the robot during the activities, which resulted with the most verbal responses (216, or 42.02%) for Nao. Lastly, a total of 57 gestures were coded based on head movements and hand gestures. We noticed a very few gestures, for example, a participant nodded their head when a robot was telling them something and they did show some pointing when choosing the robot for the activity; Vector received most gestures from the participants. Overall, the annotation counts suggest Nao was perceived as more engaging as participants showed the most gaze, facial expressions and verbal responses towards it, followed by Miro and Vector.

4.2.2 Communication Challenges

Participants faced various communication challenges with the robots, primarily stemming from difficulties in hearing or understanding the robots, particularly noted by five participants. In a few cases, the researcher had to repeat robots' statements. Participants mentioned concerns regarding robots' voices and the presence of different accents as the primary reasons behind these challenges. As a result, participants thought that most individuals in Pakistan would struggle to understand the robot. They emphasised the need for a national or local language support:

> *"Indigenous language should be used. Not everyone can understand English. There might be a person who does not understand even Urdu but imagine a robot that is able to answer in any language they speak e.g., Punjabi, Pashto, Urdu".* (P3, Man, 59)

One participant (P7, Man, 61) highlighted the low literacy rate among older adults in Pakistan. He pointed out that this could be a major obstacle in adopting social robots. P7 also expressed his concerns about addressing the social needs and language barriers specific to older adults in this demographic. He emphasised that the language barriers might limit the scope of interactions between older adults and social robots, which could have a negative impact on their overall engagement. Another participant commented:

> *"Most Pakistani families might have an issue with the language, only educated families can speak English. If it [the robotic technology] wants to be internationally accepted then language barrier should be fixed; may be a Urdu speaking robot will be a fix to this problem".* (P11, Man, 55)

In addition to the language barriers, participants also raised concerns over robots' voices as they affected their ability to communicate effectively. Three participants (P2 aged 82, P12 aged 72 and P13 aged 52) mentioned that Miro and Vector had a very robotic, mechanical voice, which made it difficult for them to understand the robots. One of them commented:

> *"I could not understand Vector at all. Nao had a very clear voice".* (P13, Woman, 52)

Table 3 Descriptive statistics on user acceptance parameters

Parameter	min	max	mean	std. dev	mode
Perceived Enjoyment	1	4	3.571428571	0.70704732	3.2
Anxiety	1	4	2.357142857	0.737368879	1.75
Perceived Adaptability	1	5	3.619047619	0.823474452	4
Perceived Ease of use	1	5	3.514285714	0.8172751	3.4
Perceived Usefulness	2	5	3.80952381	0.876374497	4

4.3 Acceptance: Interaction with the Robots

4.3.1 Acceptance Results Based on the TAM 2 Questionnaire

The results of descriptive analysis for each acceptability parameter (perceived ease of use, perceived usefulness, perceived enjoyment, perceived adaptability, and anxiety) revealed patterns related to users' perceptions of the social robots. Specifically, we found that anxiety was rated relatively low when it came to the use of social robots, whereas perceived adaptability and usefulness received higher scores. Participants generally reported lower levels of anxiety ($M = 2.35$, SD = 0.73, Mode = 1.75) compared to higher ratings for perceived enjoyment ($M = 3.57$, SD = 0.70, Mode = 3.2), perceived adaptability ($M = 3.61$, SD = 0.82, Mode = 4), perceived ease of use ($M = 3.51$, SD = 0.81, Mode = 3.4), and perceived usefulness ($M = 3.80$, SD = 0.87, Mode = 4). These findings suggest that participants were less anxious about interacting with the robots and generally found the experience enjoyable, adaptable, easy to use, and useful.

Furthermore, our analysis revealed significant correlations between certain acceptability parameters. Specifically, perceived adaptability and enjoyment were positively correlated ($r = 0.511$, $p < 0.05$, 2-tailed). This suggests that when users enjoy their interactions with the robots, they are more likely to use them, indicating a positive relationship between the likability of the robots and their adaptability. Likewise, there was a positive correlation between perceived enjoyment and perceived usefulness ($r = 0.555$, $p < 0.05$, 1-tailed). This implies that as users enjoy their interactions with the robots more, they also perceive the robots as more useful. Overall, these results suggest that the likability of the robots, as reflected in users' enjoyment during interactions, plays a significant role in their adaptability and perceived usefulness (see Table 3).

4.4 Robots' At Home: Older Adults' Perspectives

4.4.1 Robots as Assistants

Participants thought that robots could assist with specific tasks like fetching items, answering the door, or controlling lights, especially for older adults with mobility issues. Additionally, they noted that the use of social robots in home settings could help reduce feelings of loneliness for the older adults who are living away from the rest of their family. One participant stated:

> *"It can help us in fetching TV remote and check who is at the door. Sometimes, an older adult only needs a small chit chat".* (P2, Man, 82)

Participants also agreed that robots could have a place in their homes, as they could assist them with simple tasks at home, especially as people may lose their ability to take care of themselves:

> *"Well, I feel one should try to push oneself as much as they can.* [However,] *if there is a point when they think it's not possible to do things anymore, then robots can help given that you don't have any other choice".* (P5, Man, 51)

4.4.2 Robots as Guardians

During the interviews, a recurring discussion emerged highlighting participants' desire for robots to play a role in monitoring and supporting their paid caregivers and the domestic help, such as nurses and housekeepers. In Pakistan, the use of paid help is prevalent in many households for tasks such as cleaning, cooking, and caregiving. As such, participants felt that monitoring domestic workers (nurses) would be an ideal task for a robot on top of its other features:

> *"My daughter's great grandmother in law is 96 and totally bedridden. She needs two nurses full time and they give them 40k (PKR) salary each. So if there is a robot, it can help the lady and also it'll be one time investment and more reliable I would say. It can not only keep an eye on the nurses but also the kids at home if they are alone".* (P14, Woman, 52)

In addition, participants mentioned concerns about potential abuse or neglect by caregivers or domestic workers, which could be addressed through robotic assistance in monitoring their actions. For instance, one participant shared a concerning situation in their neighborhood where an elderly individual relied on a live-in maid who occasionally showed abusive behavior. In this context, participants thought that robots could act as guardians or monitoring tools, as these two quotes illustrate:

> *"It [robot] can make sure that maids are right on time in the house for elderly. We hear about the older adults being abused by their caregivers, so the robot can make sure that the maids and nurses are doing their job properly"* (P10, Woman, 51)

> *"I have a neighbour who is living alone and she have a 24/7 maid who can talk to the lady, help with cooking, deal with the guests and any emergency situations, maid knows which medicines to give. But we have heard that the maid is sometimes abusive with the lady. So the robot can report the abuses".* (P5, Man, 51)

4.4.3 Negative Impact of Robots

However, despite the potential benefits, participants preferred that care-based support come from family members. They were worried that robots at home might give children a reason to distance themselves from their parents, potentially leaving them to live alone. This reluctance to robots, even after understanding the study's purpose, revealed a discomfort among participants who worried about robots negatively affecting relationships with their children. For instance, one participant remarked:

> *"If a child want to spend time with the parents, they will do it no matter what. If they don't want to spend time with their parents, they will use the robot as an excuse".* (P14, Woman, 66)

In addition, some participants had concerns regarding the impact on their independence. For example, P5 (man, 51) stated that he was reluctant to welcome a robot in his home as he did not need one. Another participant also highlighted his desire to maintain independence:

> *"I can have a robot at home, but I don't want to be dependent on it - ever. It'll be a nightmare for me to be dependent on a machine".* (P8, Man, 62)

Overall, participants' perceptions of robots, particularly in the context of family dynamics and preferences, revealed complex emotions and concerns regarding the potential impact of robots on family relationships and independence in older age. However, one participant pointed out that things change and evolve, and with time robots may become common:

> *"I feel that in my childhood, it was impossible to send girls to schools so I think we have learnt it overtime and I have seen that even everyone now trying their best to send their girls to schools. Time has taught people the importance of education. So we need to learn and accept this thing. One person in the family*

needs to take hard steps and that motivates everyone else. Same goes with the use of robots in Pakistan". (P11, Man, 55)

5 Discussion

Caring for older adults can be challenging in many countries for multiple reasons, such as the growing demand for healthcare services, specialized care facilities, and more. Social robots have emerged as a promising alternative to address some of these challenges by providing companionship, assistance with daily tasks, and supporting health monitoring [37], [36]. However, the use of social robots in caring for older adults depends on various factors such as technological literacy [102], acceptance by both the older adults and caregivers [103], and cultural and ethical considerations surrounding their use [104]. Our work extends previous research on social robots and older adults (e.g. [6, 7, 8, 10, 11]) by presenting the perspectives of Pakistani older adults and the socio-cultural factors that could influence the engagement and acceptance of social robots in the home environment. In the following sections, we discuss the implications of our results and what needs to be addressed to make social robots more suitable for Pakistan and the GS.

5.1 Culturally Appropriate Robot Design

While previous research has shown the potential of robots to support older adults [36], it is important that robotic system designs are aligned with older adults' preferences and cultural values [105]. As people's preferences and perceptions towards robot designs and uses vary according to the specific socio-cultural context [106–108], Pakistani older adults have specific views regarding robot assistance. For example, similar to previous work [109], our participants preferred the human-like robot (Nao) compared to animal-like (Miro) and a toy-like (Vector) robot. There are two potential reasons for this. First, the humanoid robot closely resembled the image of a robot participants had in mind, most likely popularised through movies and media. Second, pets are not as common in Pakistan compared to other countries [110], which might explain the lack of interest in an animal-like robot [111]. Previous literature shows that people in the GN find it easy to form an emotional bond with animals, making the idea of an animal-like robot companion more appealing and relatable [112, 113]. However, this may not be the case for Pakistan and should be taken into account when developing robots for GS settings.

Another cultural difference was reflected in participants' expectations towards the tasks a robot could be suitable for and what its role at home could be. In particular, our older participants expressed a preference for human support over the idea of robots potentially helping them in their homes. This may be because it is more common for people in an average Pakistani household to hire house help and/or paid nurses to assist them with daily household chores, and to help older adults who can no longer take care of themselves [114]. Additionally, these services are easily available and affordable in Pakistan [115]. In contrast, our previous study conducted in the GN have shown that informal caregivers (usually family members) of older adults were interested in using robots to help with medication management [116]. This highlights a tension between the preference for human support due to the common practice of using human help and the interest of families in using robots to make their lives easier. While this could be achieved by deploying robots in the home to enable home monitoring for safety purposes (similar to previous literature[117]), there is an ethical challenge associated with constantly monitoring someone – especially in the context of domestic labour surveillance, who may not be able to communicate with the robot themselves [118]. Moreover, cultural differences influence how people assign responsibility to robots in moral scenarios, especially when something goes wrong. While many perceive robots as less morally accountable than humans, they still impose moral expectations on them [119]. For that reason, before designing robots for Pakistani or other GS home settings, there are a few questions researchers need to ask themselves to make the robots culturally appropriate:

- What are the needs of the community (e.g., older adults, their families and caregivers) that this robot is intended to serve?
- How can this robot be designed to respect and align with the socio-cultural norms (e.g., family settings, language) and practices of the community, i.e., to deal with large households where many families living in the same household?
- How might the introduction of this robot impact the community's values and traditions, e.g., cultural and family traditions?
- What are the potential ethical concerns that need to be addressed? How could the robot affect both users and non-users?

It is important to take into account the cultural values and practices of the community when designing robots for their use [106, 107]. By doing so, we can ensure that the robots are not only useful but also culturally appropriate and acceptable, ultimately leading to better communication and more effective support for older adults.

5.2 Addressing Language Barriers

Participants also highlighted potential communication issues. Even though they were fluent in English, language barriers emerged as a factor influencing the acceptance of social robots. There were multiple reasons for this, including the fact that each robot had different, though standard, English accent suitable for English-speaking regions, different pitch and volume [120]. While the voice of robots does not significantly influence native English speakers [121], it can influence non-English speakers. It is no wonder then that participants expressed the desire to communicate with the robot in their native language, which is in line with research that shows that older adults prefer the robots that could communicate in their preferred language [122].

This is an important suggestion, as English is not the primary language in Pakistan and local English accents may differ from the robots' accent. Recent research has highlighted that the current voice design of social robots does not take accent bias into the account accent [120]. This means that it does not consider the fact that people come from diverse backgrounds and may have significant variations in their accents and dialects. Modern digital agents usually communicate in standard language and use voices with standard accents, such as Southern Standard British English or General American [120]. Furthermore, research has shown that language barriers can lead to misunderstandings, misinterpretations, and in some cases, even conflicts [123]. Therefore, it is important to consider language preferences and accents when designing social robots for diverse populations. In the case of Pakistan, it would be beneficial to incorporate local accents and allow for communication in local language to increase the acceptance and effectiveness of social robots.

Our results echo research by [124] who played games with older adults from New Zealand but used different cultural terms in the communication. They observed that older adults felt uncomfortable when the robot reflected a culture that was unfamiliar to them or used the language that they were not familiar with, especially in the cooking game when the local ingredients had different names [124]. This further emphasises the need to address language aspects and make them personalised when designing and deploying robots, particularly in contexts where cultural norms and values significantly influence the perception of technology [125, 126]. In the context of social robots, this means that the robots should be designed to adapt to the language and cultural preferences of the users. This can be achieved through the incorporation of local accents [127], the use of familiar cultural references [107], and the ability to communicate in local languages [128] not only with older adults but also with their family and caregivers.

5.3 Family-Centered Approaches

Finally, our study shows that older adults living independently were reluctant to have the robot in their homes as they felt that the robot might replace the companionship and care traditionally provided by their children. One key aspect to consider is the potential role of robots in providing care and companionship. While robots can offer assistance with tasks such as medication reminders [31], they may not be able to fully replicate the emotional support and companionship provided by human interaction [36]. Older adults may fear that relying on robots for assistance could lead to feelings of isolation or detachment from their families [34].

In the GS, the emotional bond between parents and their children is deeply rooted in their cultures [12], [129], [130] which can be the reason why older adults may see the robots as a threat to the emotional connection they share with their children. The introduction of robots into family settings may gradually reduce direct human interaction, which could weaken emotional connections and diminish the quality of parent-child relationships over time [131]. In the long term, this change could lead to increased feelings of isolation among older adults and an over-reliance on robotic companionship [132], which could effect traditional family dynamics. To address these challenges, it is important to consider the potential role of robots as a support/assistant that improves the well-being of older adults, rather than a replacement for human relationships [133], which was reflected in some of our participants' comments.

In designing social robots for older adults, researchers should ask themselves: how can we design robots that enhance the well-being of older adults while also respecting their emotional connection with their families? For this, a collaborative decision-making approach that considers stakeholders' input [134] for well-being design should be used to ensure that the preferences and needs of both the older adults and their family caregivers are taken into account [135]. Additionally, social robots can be designed to bridge the gap between older adults and their families, particularly when physical distances separate them. By considering these factors, we can design social robots that are not seen as a threat to the emotional connection between older adults and their families but rather as a valuable tool that can improve the quality of life of older adults.

6 Limitations and Future Work

Our study had some limitations. First, the number of participants was low and most of them were in their 50s and highly educated, which may not be representative of all Pakistani older adults. However, we were still able to collect a rich data that provided valuable results. Furthermore, given the lack of Urdu support in current social robots, focus on a better education population helped to ensure that they would be able to communicate with the robot. In the future, researchers could expand the study to include a larger and more diverse group of participants to increase the generalised findings, and could explore the use of an Urdu-speaking robot.

Second, while we are in general interested in the use of robots in the home environment, this was a lab study. However, the results still provided useful insights that can be applied to home settings. Going forward, researchers could conduct future studies in more naturalistic environments, e.g. at participants homes, to better understand the attitude of older adults towards social robots.

Third, while this study effectively highlights users' first impressions, it has the drawback of not addressing how acceptance may change over time. Previous literature suggests that user acceptance can evolve [136], particularly due to factors such as the novelty effect [137]. In our future work, we plan to deploy robots in homes for older adults over an extended period. Our goal is to investigate whether user acceptance varies with the number of interactions.

Forth, the Vector robot faced some technical issues during the study that caused its delayed response and, in one instance, no response at all, which prompted the participant to choose another robot for that activity. This might be the reason the participants liked Vector the least. However, the responses and interviews made it clear that this was not the only reason and the participants were more concerned about the functionalities and appearance of Vector. In the future, better technologies could be explored to minimise the technical issues.

Fifth, we employed the WoZ technique to evaluate user interactions, primarily because there were three robots involved, which increased the likelihood of technical problems if we had chosen to use autonomous speech for all the robots. Therefore, all interactions between participants and the robots were controlled, meaning that when participants asked questions that were out of context, the robots could only respond by stating that they were unable to answer at that moment. We speculate that the robots' inability to provide all the answers may have influenced the participants' overall perceptions of them. Nevertheless, these interactions still offered valuable insights. Moving forward, we plan to implement the robots' autonomous speech in our future studies.

Finally, some participants reported difficulties in understanding the robots that went beyond accent and language issues discussed in the results. There were two reasons for this. Firstly, the study was conducted in a lab setting of a local university, and despite using a private lab space, there was still some background noise when students passed by the lab. This sometimes made it difficult for participants to understand what the robots were saying. Furthermore, two participants reported mild hearing issues. However, they met the inclusion criteria since their hearing problems did not constitute serious health concerns, and they were informed about the study's nature. To ensure that any lack of understanding of the robots was not solely due to their hearing capabilities, but could also be attributed to the robots' English accents, we increased the robots' volume to the maximum level. However, despite these issues, the participants were able to communicate with the robot and the large number of interactions enabled us to counterbalance the situations affected by noise. In the future, another study could be conducted in a quieter environment (ideally at home) and take into consideration any hearing issues of participants or perhaps investigate different communication modalities to make the robot interactions more accessible. In sum, future research can build on these findings to further explore the potential of social robots among older adults in Pakistan.

7 Conclusion

An increasing number of older adults in Pakistan could benefit from social robots to support them in their daily activities. However, the use of social robots is yet to be explored in the country. To address this, we conducted a study with 14 Pakistani older adults to investigate the engagement and acceptance of three different social robots. Our findings highlight some essential factors of social robot engagement and acceptance among older adults in Pakistan. For instance, our participants preferred the robot that looked closer to a human, which in our case was Nao. Moreover, the cultural differences and language barriers emerged as a biggest challenge. We also discussed suggestions that can make the robots more acceptable and engaging in Pakistani home environments, including addressing cultural and language barriers and prioritising a family-centered living approach. In conclusion, we provide design considerations for deploying social robots in Pakistani home settings.

Appendix

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Author Contributions The study was conceptualised and designed by SA and KS. NV and CF provided feedback on the study design. SA prepared the materials, and SA and MA collected the data. The analysis was conducted by SA, MA, CF, and KS. SA and KS were primarily responsible for writing the manuscript, with input and comments from NV and CF.

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Data Availability The datasets generated during this study can be obtained from the corresponding author upon reasonable request.

Declarations

Ethical Approval The study was performed in accordance with the ethical standards of research with human participants defined by UCP and Cardiff University ethics committee supported UCP's Ethics approval.

Informed Consent Informed consent for the data collection and publishing the findings in a research article was obtained from all participants included in the study.

Conflict of Interest The authors declare that they have no conflict of interest.

Table 4 Participants details

Participant ID	Gender	Age	English Understanding
P1	F	65	fair
P2	M	82	fair
P3	M	59	fair
P4	M	62	fair
P5	M	51	fair
P6	F	50	fair
P7	M	61	fair
P8	M	62	fair
P9	M	50	fair
P10	F	51	fair
P11	M	55	fair
P12	M	72	fair
P13	F	52	fair
P14	F	66	fair

Table 5 Cronbach's alpha

Parameter	Cronbach's Alpha	No. of items
Perceived Enjoyment	0.76	5
Anxiety	0.59	4
Perceived Adaptability	0.62	3
Perceived Ease of Use	0.69	5
Perceived Usefulness	0.85	3
Overall	0.695	14

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