Older Adults' Emotional Challenges and Co-design Preferences for a Social Robot after the COVID-19 Pandemic

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***Abstract*— Mental health challenges became more prevalent during the COVID-19 pandemic, especially among older adults. Consequently, we witnessed an uptake of new technologies, including social robots to address these challenges. However, we observed limited inclusion of older adults in the design process to design these technologies to cater user needs during the pandemic. To address this gap, we conducted a co-design workshop with 17 older adults and explored their emotional challenges after the COVID-19 pandemic. They evaluated the current social robot designs available in the literature and elicited the design preferences for a social robot to address their current emotional challenges. Our results based on thematic analysis show that the impact of the pandemic on older adults' emotional challenges is persisting, and the companionship of a social robot is preferred to enhance their mental well-being. We also show that older adults preferred an animal-like robot design embodied with soft skin possessing a medium size. These findings highlighted older adults' design choices of a social robot and affirmed their potential to support older adults' mental well-being.**

***Index Terms*— Older Adults, Mental Well-being, Emotional Challenges, COVID-19, Co-design, Social Robots**

I. Introduction

The average age of the world's population is rising, and over the next ten years, the number of older adults is predicted to rise by more than 60%, reaching 1 billion by 2030 [1]. Older adults may lose their social positions, friends, family, and health as they age [2], causing emotional challenges such as depression, loneliness, and self-isolation leading to mental well-being issues [3], [4]. The COVID-19 pandemic has nearly tripled [5] mental well-being issues due to greater stress exposure and social engagement restrictions that increased anxiety and fear levels, posing unique challenges for older adults after the pandemic compared to other age groups [6], [7]. Social robots have been suggested as a healthy ageing technology that promotes mental well-being [8]. Designing social robots need a comprehensive understanding of human behaviour, intellect, and diverse technological abilities [9]. As researchers and organisations build robots for older adults, it is recommended that they be aware of preconceived notions to understand how the technologies affect mental well-being [10]. Consequently, social robots for older adults could be designed using a User-Centred Design (UCD) approach that encourages non-designers to participate in co-design activities [11], which amplifies users' voices frequently ignored in technology design and empower them in the design process [12]. By engaging older adults in robot co-design, technology can be adapted to their demands and abilities, promoting mental well-being and ensuring more effective designs [13], [14]. Prior research in co-design methods included older adults in different technological designs, such as mobile applications [15], websites [16], smart home applications [17] and assistive robots [18].

In this paper, we present the results of a co-design workshop with older adults; we conducted two sessions – to facilitate participants to explore the emotional challenges affecting their mental well-being after the COVID-19 pandemic and to elicit their preferences for designing a social robot to address these challenges. We contribute the following:

- thematic analysis of older adults' current emotional challenges due to the COVID-19 pandemic,
- preferences for social robots in private and public environments, and
- design preferences of a social robot addressing post-pandemic emotional challenges.

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II. Related work

A. Older adults' mental well-being post COVID-19

Preventing and treating mental well-being issues is a public health priority, especially for older adults, due to their increasing rate and worldwide impact [19]. Older adults suffered mental well-being concerns before COVID-19; however, the pandemic has aggravated these issues, making them labour with significant emotional challenges. COVID-19 has caused a higher mortality rate and severe complications among older adults who lived in extreme isolation and were anxious about catching the disease [20] revealing pre-existing mental well-being issues among older adults and accentuating the need for more targeted support and resources [21]. Several technological solutions have been created during the pandemic to alleviate social isolation and help older adults [22], such as wearable devices [23], telehealth [24], virtual reality [25] and social robots [26]. However, it is essential to continue monitoring and addressing older adults' mental well-being needs even after the pandemic has ended [22] as COVID-19 has emphasised the value of technology and its effect on older adults' mental well-being through effective interventions.

B. Social robots for older adults' mental well-being

Studies on robots for older adults have focused on social and socially assistive robots [27]. Socially assistive robots (SARs) assist individuals with daily tasks, including eating, bathing, toileting, and clothing, such as Care-o-bot [28]. On the other hand, social robots have been examined as a prospective tool for enhancing older adults' mental well-being through social interactions, including conversation, companionships, and cognitive stimulation, such as Paro, Pepper, AIBO and JoyForAll [29], [30]. Most of these robots featured humanoid or zoomorphic forms with biological traits such as ears and noses [31]. Paro, a baby seal-like social robotic animal inspired by animal therapy, has been used to treat dementia, depression, and social interactions [30], [32]. Pepper, a humanoid robot, has been proven to minimise loneliness and social isolation [33], [34]. AIBO has also been proven to improve cognitive performance and elicit emotional reactions in older adults [30], [35]. JoyForAll dogs or cats are furry, touch and voice-responsive social robots designed to reduce loneliness and stress in older adults, especially dementia patients [36]; yet, they lack usable technology [37]. As there is no one-size-fits-all solution, older adults' demands and preferences greatly influence social robots' acceptability, usage, and adaptation. While the existing social robots could aid older adults' mental well-being, their ethical concerns and high cost make it essential to co-design a social robot that meets their needs and preferences since their reactions to social robots were investigated more than their preferences [38].

C. Designing social robots with older adults

Human-robot interaction researchers have used UCD methods through co-design workshops for older adults to build social robots for mental well-being, such as semi-structured interviews [39], [40] held via a series of workshops with older adults to build social robots, card sorting activities [10], [29], [41] observed older adults' social robot desires and assisted them in developing multimodal robot interfaces, tools and design guidelines [42], [43] such as canvas tool used for co-designing social robots and focus groups [38], [44] explored older adults' group technology design in design workshops. In addition, a prior study [45] assessed the importance of involving end users in the design process by comparing social robot design perspectives between older adults and roboticists. Consequently, end users and developers differ on social robot design features, highlighting the need for UCD to enable technologies to attain adequate acceptability and continuous positive results addressing various challenges older adults face, particularly after the pandemic's emotional impact [46], [47]. Prior work helps us understand the value of co-design; however, we maintain that COVID-19 has transformed our behaviours. Hence, it is essential to understand these changes to develop social robots considering older adults' preferences and promoting their mental well-being.

III. Co-design Workshop with Older Adults

We followed the dialogue-labs method to run the co-design workshop, to facilitate participation for collaborative ideation and concept development by providing structured space, materials, and activities [48] (See Fig. 1). We followed Wang et al.'s toolkit [49] on co-designing with older adults to organise the workshop. The workshop aimed to examine the current emotional challenges experienced by older adults after the COVID-19 pandemic, their preferences towards social robots in different post-pandemic environments, and the design specifications of a social robot that could address these challenges. In this paper, we employed qualitative and quantitative research methods to examine these phenomena. The utilisation of qualitative methods facilitated our comprehension of the rational reasoning (R1), while the implementation of quantitative methods enabled us to evaluate the hypotheses (H1, H2) as follows:

- **R1:** Social robots address emotional challenges post COVID-19 as they represent a promising strategy to support older adults' emotional well-being, promote social connections, and provide physical contact.
- **H1:** There are significant differences in older adults' preferences for social robots across different environments (private and public).
- **H2:** There are significant differences in older adults' preferences when specifying social robot design features.

A. Participants

We recruited the participants through email invitations sent via Swansea City Council's Ageing Well Society and Age Cymru, which is the national charity for older people in Wales, UK. Our workshop involved 19 older adults (11F, 8M, aged 65–74 years with a mean of 67.7 years). We followed the approved procedures of our Institutional Review Board (IRB) to organise and run the workshop. Two male participants withdrew during the first session, citing a lack of interest, which resulted in a final sample size of 17 participants.

B. Procedure

This workshop lasted three hours, including a 45-minute lunch break. The sessions were run as described below.

1) Introduction – (30 minutes): In this session, the participants signed an information sheet and a consent form, and completed a short questionnaire. They recorded their scores on a 5-point Likert scale for the first two questions, and answered the third open-ended question.

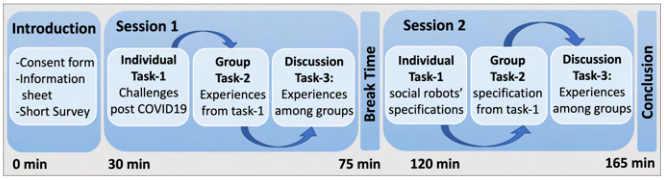

Fig. 1. Co-Design Workshops' Dialogue lab three-hour session.

i) Rate your interest in technologies, for example, smartphones, robots, and artificial intelligent systems.
ii) Rate how much emotional challenges you are still facing due to the COVID-19 pandemic, considering both negative and positive challenges.
iii) Do you have any prior experiences with a social robots? If yes, then could you please specify?

We obtained the following answers from participants:

i) Participants exhibited relatively high interest in technologies with mean and standard deviations (SD) of 3.88 ± 0.9.
ii) They experienced continued emotional challenges with mean and SD of 3.35 ± 1.46. Fourteen participants reported negative impacts on their mental well-being following the pandemic, whereas three mentioned positive changes, like satisfaction for helping others and learning new skills.
iii) Three participants reported limited experiences with social robots, e.g., through smartphone apps, local day centres and an assistive slave robot some 30 years ago. The rest fourteen participants had no prior experience.

2) Session-1: Older adults' mental well-being challenges after the COVID-19 pandemic: We divided participants into four groups considering their experience of technology and emotional challenges. They were presented with two scenarios, i.e., private and public, with corresponding materials on four tables (see Fig. 2) – two tables for private and two tables for public scenarios. Some of the examples of private scenarios were cooking, reading a book or watching TV alone at home or spending time with family members. Some of the examples of public scenarios were hospital appointments, meeting in community centres, group activities and public transport. These facilitated the participants to explore their emotional challenges via storyboarding using images, artefacts, papers and postcards and encouraged use-case ideation without overwhelming them [50]. Each group was assigned to one facilitator who led the discussion with the participants. In addition, two observers moved between groups noting emerging common themes. The observers and facilitators recorded participants' thoughts and discussions in notebooks, photos, and voice recordings. We assigned the groups to complete three tasks during the 45 minutes.

Task–1 (individual, 15 minutes): In this task, the participants worked on individual worksheets on their tables. The facilitator encouraged them to recall three real-life situations for their private or public scenario using the co-design materials and reflect on the corresponding emotional challenges and the continued effect of COVID-19. They then recorded the importance of the three situations and the corresponding emotions on a Russell's 2D emotional wheel [51] (see Fig. 7).

Task–2 (group, 15 minutes): In this task, the facilitator encouraged the group to discuss each other's recalled experiences from task–1 and populate a new worksheet for the group with their top three important situations and emotional challenges related to the COVID-19 pandemic.

Task–3 (discussion, 15 minutes): For this task, the participants nominated a person from their group to share their top three experiences and emotional challenges with other groups. This followed an open discussion between participants sharing their negative and positive experiences related to COVID-19. The facilitators and observers noted the common themes.

Fig. 2. Some examples of the materials from session –1 are shown. They presented private and public scenarios to explore their emotional challenges.

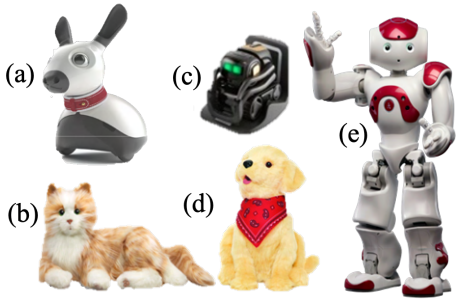

Fig. 3. Five different off-the-shelf social robots–not in scale: (a) Miro (Miro-E), (b) JoyForAll cat (JoyForAll) , (c) Vector (Robots-IEEE), (d) JoyForAll dog (JoyForAll), (e) Nao (NICEPNG).

3) Session-2: Older adults' preferences for a social robot and its design: In this session, we first introduced a video illustrating different types of social robots, such as educational, companion, socially assistive, entertainment, and medical robots. Then, we presented how some of these robots positively affected mental well-being, e.g., Paro and JoyForAll aiding dementia patients [32], [36]. We then distributed five commercial social robots, i.e., Miro-E, Vector, JoyForAll cat, JoyForAll dog and Nao, see Figs. 3 and 4. This encompassed a humanoid, animal-like and toy-like robot with various feels (soft, hard, furry, etc.), sizes, behaviours and interactions. The facilitators helped the participants to discover various features of the robots, giving them insights into social robots and their designs [43]. We then encouraged the participants to consider various robots from the videos and the pre-distributed ones to address their emotional challenges (see Fig. 4). They performed the following three tasks during the 45-minute session without changing their table.

Task–1 (individual, 15 minutes): In this task, the facilitator asked older adults to individually co-design the social robot addressing the challenges observed in session-1 with an integrated canvas specification worksheet inspired by the Modality Card Deck [41] and canvas tools [42] see Figs. 5 and 6. We followed Wang's [49] guidelines and checklist for developing tools for co-designing with older adults on behaviour change to create our activity worksheets.

Task–2 (group, 15 minutes): In this task, facilitators asked participants to blend their ideas as a team by presenting their designs to each other and co-design a new social robot.

Task–3 (discussion, 15 minutes): For this task, facilitators asked all groups to share their designs and explore session-2 ideas in two different environments, i.e., private and public.

We ended up with a conclusion (15 minutes) and summarised the key insights from the workshop. We used this approach to lower participation barriers by giving them control over the design content and a shared understanding of their thoughts to criticise and improve the design as a group.

IV. Results

We present the key findings of our workshop on analysing the data from the two sessions. In session-1 we encouraged the older adults to explore emotional challenges they face after the COVID-19 pandemic, while in session-2 we explored older adults' impressions of social robots and how these robots could enhance their mental well-being. We have utilised both qualitative and quantitative methods to analyse the data which are presented next.

Fig. 4. Older adults engaged with different types of social robots which gave them the insight to design their own robots in session 2, as shown.

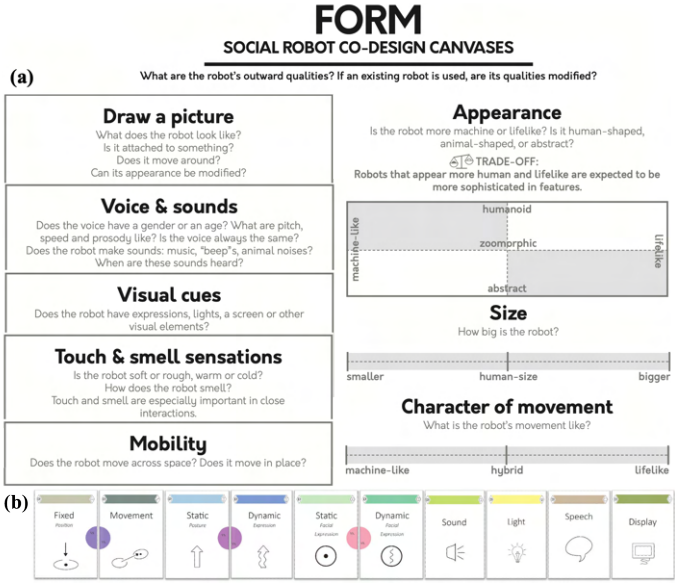

Fig. 5. (a) Modality Card Deck tool by [41] represents different modalities a robot can use to communicate. (b) Canvas tool of the robot describes the robot's outwardly perceptible qualities by [42] (for the sake of this paper white space is removed).

A. Thematic Analysis

We applied thematic analysis [52] to our data, overseen by three researchers to identify and analyse patterns and common themes for both sessions through open coding and notes from participant discussions.

1) Session-1: Our qualitative investigation of session-1 focused on how the pandemic revealed four high-level themes: Social Relationships, Emotional Disorder, Physical Contact and Emotional Strength. We identified 64 codes linked to use scenarios and instances of older adults' emotional challenges due to the COVID-19 pandemic.

Older adults struggle to engage with others and retain social relationships: Seven participants stated missing family, friends, relatives, neighbours, and community centres made it hard for them to maintain social relationships after the pandemic. This lack of social contact caused older adults to feel upset and lonely, as one participant mentioned, *"Due to the pandemic, I could not contact my relatives frequently, and many of them were unresponsive left me feeling disheartened" [P17].* One of the primary reasons why social relationships

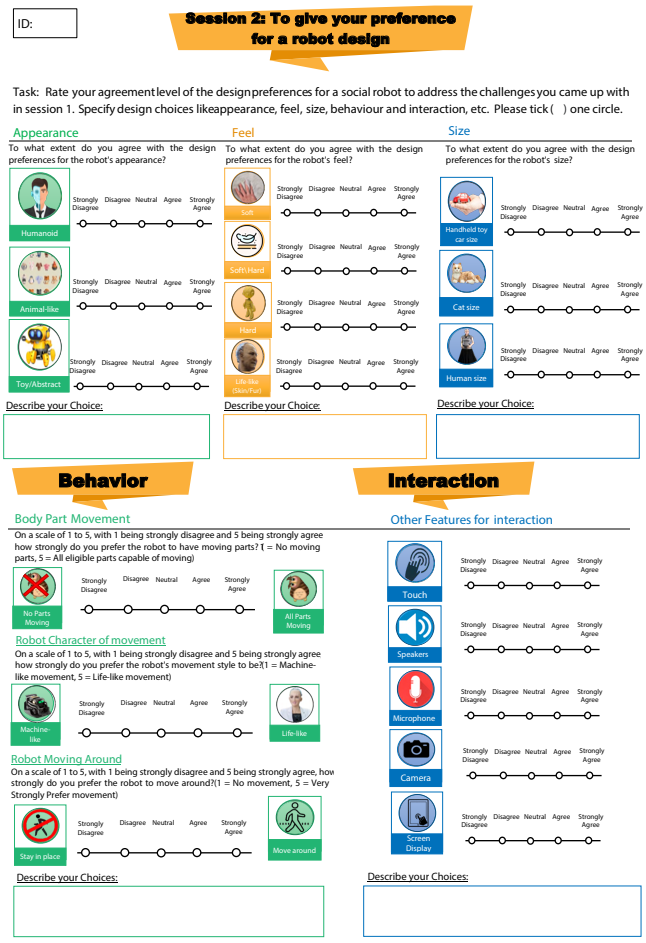

Fig. 6. Session-2 social robot design preferences integrated worksheet.

did not revert to pre-pandemic levels is the fear and uncertainty surrounding the ongoing COVID-19 pandemic, as one participant expressed, *"Since I live in a village, I could not engage socially. Even though the pandemic has ended, a sense of fear has developed within me that I have lost connections and relationships" [P1].* Therefore, older adults need social connections since the lack of social interaction during the pandemic has reinforced fear and uncertainty, making it difficult to rebuild these relationships, and many older adults remain hesitant to resume social activities despite the vaccine's availability.

Prolonged negative impact on mental well-being: Emotional disorder as a negative impact rated by 14 participants as a factor affecting their mental well-being, including depression, anxiety, stress, fear and lack of motivation exacerbated by fear caused by lockdowns and social distancing that persisted beyond the COVID-19 pandemic as one claimed, *"I was concerned from morning to night, following the media. Thus, I earned an unwanted and persistent habit of tracking COVID-19, followed by being depressed by climate change and global issues" [P7].* Another participant reported being less motivated than usual, *"I am usually very active, and after the pandemic, I am not motivated" [P14].* In addition, the restrictions imposed by the pandemic in public places, especially hospitals, such as social distancing and wearing a mask, made it difficult to provide the routine healthcare that older adults were used to in the past, and increased levels of anxiety among vulnerable older adults, especially those with pre-existing mental well-being, as one mentioned, *"Restrictions such as social distancing and mandatory wearing of masks in hospitals lead to a loss of facial/non-verbal communication, which leads to a lack of support and misunderstandings" [P3]*, thus older adults need emotional support, as the pandemic has led to the enrichment of emotional disturbances that persist for a long period lead to a marked negative impact on mental well-being.

Absence of physical contact increased the feelings of anxiety: The lack of physical contact during the pandemic experienced by eight older adults contributed to the continued fear of physical contact with others even after the pandemic, as one participant expressed, *"While we were under lockdown...one day I was walking around. Suddenly, a dog licked my hands; it was such a shock that I almost burst into tears and felt upset by realising that I hadn't had a human touch for three months. I missed this physical contact because I lived alone" [P7].* The absence of physical contact led to feelings of anxiety and frustration among older adults as the same participant P7 expressed, *"My obsessive tendencies and the continual feeling that time is running out have made me tense and anxious; this persistent sense of urgency has impacted my well-being".* As people age, their perception of time changes, and they prioritise goals that emphasise emotional satisfaction and maintain emotional well-being. In addition, the fear of physical contact after the pandemic may be due to the prolonged period of social isolation and the development of new social norms emphasising physical distancing, as P12 expressed his constant fears that others do not adhere to these restrictions, *"Although I enjoy travelling, I still worry about travelling and avoiding crowded indoor places".* Thus, the absence of physical contact during the pandemic increased the fear of older adults going out and engaging in public places for fear of catching new infectious diseases.

Positive changes brought on by COVID-19: Emotional strength focused on the positive changes experienced by older adults in the post COVID-19 era. Eight participants reported feeling happy and more confident after the pandemic, as one stated,*"I am happy because no more house arrests, bus services and all stores are open. No social distancing and life are back to normal" [P2].* Two participants (P4, P8) mentioned respectively gaining confidence and learning new skills that made them happy and desired to help others, stated, *"My confidence was affected during the pandemic, but now it has grown and I became more alert"* and *"I found joy in learning new skills which will allow me to help others going forward".* These positive changes suggest that some older adults could adapt to the changes brought on by COVID-19 and have emerged with a newfound emotional strength.

Our thematic analysis revealed the profound impact of COVID-19 on older adults' mental well-being, emphasising the urgency for interventions addressing their emotional challenges as its effects are ongoing. Hence, social robots represent a promising strategy that can support mental well-being, promote social connections, and provide physical contact.

2) Session-2: In the second session, we further explored older adults' impressions of social robots and how these robots could enhance their mental well-being through four overarching themes by 40 identified codes linked to the preferences of older adults on the types of social robots and how these robots could address the emotional challenges mentioned in session-1.

Social Interaction: The first theme explored in session-2 was social interaction, centring on older adults' challenges in maintaining social relationships. Seven participants recognised the potential of social robots to help them connect with others and reduce feelings of isolation and loneliness, as one participant stated, *"I saw a medical robot called Grace...it reminded me of a family member. I realised that having such a robot would keep me connected, reducing isolation and depression" [P17].* Participants highlighted the importance of real-world interactions for social robots as they mentioned (P16, P15) respectively, *"Interactions are crucial to me, as I want the robot to facilitate socialisation and connection,*

reducing isolation and making me feel connected" and *"I am looking for a robot that can autonomously perform tasks and respond to voice commands, which would alleviate my loneliness"*. Hence, social robots have the potential to address not only practical needs but also emotional ones by fostering a sense of connection and reducing feelings of isolation and loneliness.

Emotional Support: The second theme that emerged from session-2 is emotional support, which focuses on addressing the emotional disorder, covering the negative emotions that impacted mental well-being reported by nine participants as (P7, P13) noted respectively, *"Because I live alone, the companionship of a social robot will make me happy and more relaxed, reducing my stress and loneliness"* and *"I think a social robot makes me less stressed as it would interact with me using facial expressions such as moving eyes and mouth"*. These comments highlight the potential of social robots to provide emotional support and relieve feelings of stress and loneliness, particularly during times of social isolation. Additionally, another participant stated, *"During the pandemic, many people felt lonely and depressed due to the loss of social communication, so having a robot that can talk and listen to you would make people feel much warmer and not depressed" [P22].* Overall, the participants viewed social robots as a viable solution to their emotional issues, demonstrating the potential benefits of addressing the disorders caused by the pandemic.

Enduring Companionship: The third theme from session-2 is enduring companionship which pertains to the lack of physical contact that left older adults dissatisfied and disconnected from relatives, resulting in lingering apprehensions regarding physical contact even after the pandemic. Ten participants expressed interest in having social robots as pet companion robots; one participant stated, *"Having an animal-like companion robot with a soft texture that can be stroked or cuddled provides a good feeling and can reduce anxiety and make me feel more relaxed" [P11].* Participants (P7, P13, P9) respectively mentioned the importance of tactile interaction with a social robot stating, *"I want a companion robot because I like its tactile interaction and feel when I am physically in contact with it, where I can cuddle it, making me less anxious and happy"*, *"I think having a companion robot that gives a feel like latex or velvet suede to be like a surrogate pet would reduce my stress and anxiety because I will be able to come into physical contact with it"* and *"I prefer having a companion robot that resembles an animal-like a dog or a cat, with a furry/soft texture that I can stroke it, giving me a good feeling"*. Therefore, social robots with enduring companionship can reduce anxiety and stress by incorporating soft and tactile textures simulating the comforting touch of a real animal and creating a more practical sense of companionship.

Older Adults' Accessibility: The final theme identified in session-2 was older adults accessibility, a critical consideration in designing social robots for older adults. Seven participants shared their perspectives on the challenges of caring for real pets as they age due to physical limitations as stated, *"The older we get, the less we can look after a real pet, as they need cleaning, feeding, and walking. In addition, our hearing loss increases as we age, so a social robot that provides companionship with a display screen would also help assist the deaf and have speakers and volume control to aid people with visual impairments" [P12, P11].* However, a potential privacy issue was raised with incorporating a display screen, camera, and microphone as P17 stated that, *"A display screen may threaten me if I don't know how to use it"*. To ensure that social robots are accessible and user-friendly for older adults with physical and sensory impairments, it is essential to balance practical features with privacy concerns. As P4 noted, *"It is essential to design robots to assist impaired individuals by incorporating features such as cameras, microphones, and screen displays in robot interactions, yet it could invade the user's privacy"*. Thus, it is important to consider accessibility, ease of use and privacy concerns when designing social robots for older adults' needs as they age.

Overall, these qualitative findings highlight the potential of social robots to support older adults' emotional and social well-being. Participants realised this by adapting the robots' capabilities to their needs, including the potential to help them connect with others, reduce loneliness and anxiety, and address emotional challenges. Consequently, they desired a companion pet robot that could provide emotional support, enduring companionship, meaningful social interactions and ease of access.

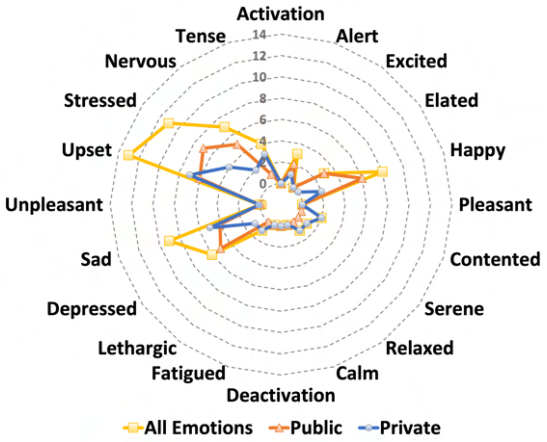

Fig. 7. Older adults' emotions experienced.

B. Older adults' emotions through environmental context

In this section, by applying qualitative and quantitative analysis, we explored the relationship between older adults' emotions experienced due to the challenges mentioned in session-1 and user preferences for social robot design in private and public settings. The qualitative phase explored individuals' emotional experiences with social robots in private and public contexts by choosing an emotion from the emotional wheel and writing down their thoughts. We illustrate the emotions experienced (see Fig. 7), showing 18 emotions covering two scales (valence and arousal) based on Russell's 2D approach [51]. We plotted three series displaying older adults' expressions of each emotion in private, public, and both environments. The yellow line with square mark points indicates emotions in both environments; the highest emotion felt by 13 participants was upset, 11 participants were stressed due to loneliness and lack of physical contact, while eight participants felt happy due to no more lockdown. The public environments in the red line marked with triangle points show that seven older adults were more stressed and five were depressed, despite the persistence of the impact of COVID-19 as people are afraid to leave their homes, while six older adults had happy feelings because public places are open and no more restrictions. Conversely, the private environment in blue with circle points illustrates that older adults mainly feel stressed as claimed by seven participants, and feeling sad as indicated by five participants due to loneliness, while only two participants had happy feelings as their confidence was boosted, yet all participants agreed that the pandemics' impact is ongoing. In the quantitative phase, participants rated their design preferences for social robots in private and public environments. To evaluate users' preferences for social robots, we performed an ANOVA: Two-Factor With Replication test, hypothesising no difference between private and public environments when specifying social robot preferences. The findings indicated a significant impact

on the environment, suggesting that older adults preferred social robots in private over public settings by a low *p-value* < 0.01 from the interaction effects between environment and design preferences. Linking qualitative emotional responses, such as fear and loneliness associated with leaving home for public settings, with quantitative design choices revealed a clear correlation. This relationship affects those afraid to go out and feel lonely at home. The results show that private environment emotional connection and security substantially impact their choice of private environment social robots. Social robots may help those who worry in public spaces and feel lonely by giving companionship and support in their homes. These findings demonstrate the relevance of design factors and individual traits such as age in social robot development. They also emphasise the environmental contexts' impact on design choices. Understanding these aspects increases social robots' ability to meet users' needs and boost their experiences.

C. Design preferences

The quantitative section of session-2 covers the social robot design preference activity using the worksheet shown in Fig. 6 that consists of several categories divided into five sections (appearance, feel, size, behaviour, and interaction). The participants were asked to rate each of these categories by expressing their level of agreement based on a 5-point Likert scale (1—strongly disagree to 5—strongly agree) and had the freedom to describe their choices. The social robot design specifications were examined on 17 older adults' design preferences addressing the emotional challenges they came up with in session-1. We present the findings as means, SD and medians (see Table. I). Due to ordinal data from social robot design specifications, we employed a non-parametric Friedman test to rank order two or more items [53]. We required each participant to encounter distinct experimental circumstances in all five categories with a statistical value considering the significant level of 5%, hypothesising that there is no significant difference between the features under each category. The social robot's appearance strongly agrees with older adults perspective as animal-like by claiming that it is more friendly and companion, while 11 participants stated humanoid robots are freaky and six participants claimed that a toy/abstract robot do not give a natural feeling. The test demonstrates that older adults prefer animal-like social robot designs with a critical value *p=0.026*. The feel of the social robot was preferred to be a fur texture and more life-like that can be stroked or petted, reducing anxiety, whereas the social robot's hard rigid feel rated the lowest. Four participants preferred a social robot like the JoyForAll, which has a soft exterior and a tough interior, giving a feeling of a real pet's body. Thus, older adults favoured a soft social robot design texture with a critical value of *p=0.0014*. The older adults also desired the robot to be medium-sized, more like a pet, confirming a significant value with *p=0.00021*. Consequently, older adults favoured the robot's dynamic body categories to react naturally and smoothly, yet few preferred to avoid the robot's moving around as it scared them. Instead, most participants preferred a robot with facial expressions as they described their choices in the worksheet blank boxes (Fig. 6); hence the test indicates no difference in design preference for all these behaviours with value of *p=0.53*. Finally, with a critical *p=0.24*, all types of interactions were desired to be incorporated into the robot design showing no significant difference, making it an intuitive companion pet robot.

TABLE I

OLDER ADULTS' PREFERENCES FOR A COMPANION ROBOT DESIGN

Category	Features	Mean ± SD	Median
Appearance	Human-like	2.1 ± 1.6	1
	Animal-like	3.7 ± 1.5	4
	Toy/Abstract	2.1 ± 1.3	2
Feel	Soft as toy	3.5 ± 1.2	4
	Soft exterior, tough interior	2.9 ± 1.2	3
	Hard as plastic body	1.5 ± 1.0	1
	Life-like as skin or fur	2.9 ± 1.4	3
Size	Small (handheld toy)	1.6 ± 0.7	2
	Medium (cat size)	4.1 ± 1.2	4
	Large (human size)	2.5 ± 1.4	2
Behaviour	Moving body parts	3.6 ± 1.2	4
	Life-like movement	3.5 ± 1.4	4
	Moving around	2.8 ± 1.5	2
Interaction	Touch	3.2 ± 1.3	4
	Speakers	3.8 ± 1.1	4
	Microphone	3.4 ± 1.1	4
	Camera	3.0 ± 1.2	3
	Display Screen	3.1 ± 1.5	3

V. DISCUSSION

1) Emotional well-being: Our research findings of four high-level themes on the emotional challenges revealed that COVID-19's impact on older adults' mental well-being persists. As the pandemic has raised fear and uncertainty, it is challenging to restore older adults social relationships and revert to pre-pandemic levels, causing them to feel more isolated and lonely. Furthermore, the pandemic has exacerbated long-term emotional disorders, such as depression, underlining older adults' need for emotional support. In addition, the lack of physical contact during the pandemic generated anxiety and dissatisfaction in older adults resulting in more loneliness, as they fear engaging in public places due to new diseases. However, eight older adults showed positive feelings as they can adapt to COVID-19 changes. Our analysis reinforces that older adults are particularly vulnerable to the negative emotional impacts of COVID-19 in line with previous research [54], [55]; however, our workshop covered the consequence of its effect after the pandemic. We classified older adults emotions using Russell's 2D emotional wheel [51] in session-1 activity based on their positivity/negativity level of intensity. We subsequently expanded Pollmann's [41] concept of expressing emotions instead of using Emotion Cards to reflect older adults' feelings. Therefore, our workshop is consistent with prior work highlighting the potential need for tools to record older adults' emotions [51], [56]. Due to the pandemics' long-lasting consequences, social support will remain essential for older adults struggling with emotional issues suggesting that using social robots could significantly enhance older adults' mental well-being. Our co-design workshop revealed the need for social robots designed to support long-term user needs, given the emotional challenges associated with the post COVID-19 period. Thus, the emotional challenges that we have discussed implicate that the design of social robots is not short-term but actually long-term.

2) Social robots: Older adults' responses to social robots have been studied more than their preferences, revealing a mismatch between robotics and their demands [38]. Current social robots Paro and AIBO engage with users using only nonverbal vocalisations and modest motions [57]. Our promised results indicate that older adults prefer an interactive companion pet robot, indicating the appearance of animal-like, soft-feel, medium-size, dynamic body parts, facial expressions, and all types of interaction with verbal responses, as speakers and microphone features were most desired, making the robot more natural. Thus, diversity of engagement and responses is necessary for higher interactivity. In addition, JoyforAll pets may not be as technologically sophisticated as other social robots, and people may find them less appealing since they lack the emotions and actions of a real pet [37]. Hence, to ensure that social robots meet older

adults' emotional needs, designers could prioritise affordable and accessible social robots and consider ethical concerns when building these technologies by revealing end-user design preferences through a user-centred design process.

3) Co-design workshops: Co-design workshops have been used successfully in previous research to involve older adults in designing technologies that meet their specific needs [13], [14]. In this research, we performed a co-design workshop with older adults to explore social robot design, which revealed their preferences. Robot designs have focused on the stereotypical older adult as lonely and requiring significant support showing the need to reflect diverse preferences adequately [45]. Consistent with previous research on how older adults engage in group activities to conceptualise technology for themselves via a workshop [44], we investigated the design process through individual and group activities, participants designed for themselves and then for others without personalising, helping us understand diverse participants' requirements. Consequently, older adults specified the social robots' design preferences to a companion pet robot by an integrated canvas specification worksheet inspired by the Modality Card Deck [41] and canvas tools [42] to make the activity more suit our needs and use it with older adults. Our workshop examined the mental well-being of older adults in a local city following COVID-19, yet our qualitative transcriptions provided confidence in the results. The employment of social robots for the benefit of older adults will not be limited to COVID-19 but can be applied more broadly to include providing emotional support, assisting therapists, and reducing loneliness in healthcare, treatment and gerontology. Furthermore, we aim to address mental well-being issues in general by covering a more comprehensive sample of our participants from different cultures and considering ethical concerns while building social robots in the future.

VI. Conclusion

In this paper, we explored the co-design of a social robot with older adults to address their emotional challenges post COVID-19 pandemic. The participants explored their emotional challenges as a consequence of the pandemic in various private and public scenarios with photos, videos and discussions in the first session, and reported feeling sad, upset and stressed, as well as happy to help – implying the effects of COVID-19 on their mental well-being are persisting. They then explored various social robots with photos, videos and commercial products, and reported preferring companion pet robots to address their emotional issues and enhance their mental well-being. They specified robot designs that are soft to touch, medium sized to hold with life-like movements, which could respond and interact via touch, auditory, speech and vision and information display. We believe UCD and addressing the unique needs of older adults provide valuable insights for researchers to develop meaningful social robots for this population. We hope that our work would inform the development of future social robots for older adults to address their emotional challenges and mental well-being.

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