Walking Outdoor with a Zoomorphic Mobile Robot: Exploration of Robot-Assisted Physical Activities for Older Adults

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***Abstract*— In the field of human-robot interaction (HRI), assistive robots have been integrated to promote social interactions and physically active lifestyles in the wellness context of eldercare. Despite their potential benefits, the current applications of assistive robots are constrained by limited usage environments and their predefined roles. Our research aims to explore older adults' perceptions of assistive robots and approaches for delivering motivational physical activities by integrating, Spot, a zoomorphic mobile robot, as an outdoor walking guide. We conducted a participatory design study at a Finnish nursing home, consisting of three phases: the co-design workshop, the conceptual design, and the field study. This qualitative research collected data through observations and interviews. The findings report positive attitudes and natural social interactions among older adults during the outdoor physical activities assisted by the Spot robot. Based on these findings, we present a set of design implications for wellness robots in eldercare, including robot roles and tasks, methods for introducing robot literacy, and approaches to presenting robotic solutions to older adults.**

I. Introduction

Regular physical activity has positive contributions to disease prevention and improved mental health [1], [2]. Given that sedentary behavior tends to be more common among older adults (aged 65 years and above), it is becoming increasingly important to promote regular physical activity as a means of maintaining their quality of life [1], [5]. Emerging technologies such as robotics have been used as a tool to assist and engage older adults in physical activity [6]. Assistive robots refer to technologies that aim to maintain the independence of older adults by providing support for mobility, health monitoring, and social activities [18]. Related research indicated assistive robots have proven to fulfill various users' needs with the consideration of accessibility and usability [7]. Although assistive robots have great potential in the wellness context of eldercare, their current applications are constrained by the usage environment and specific roles they have been assigned. For instance, socially assistive robots that have animal-like appearances [8], [9] or screen-based interfaces [10], [11] are developed as home-based robots to provide companions and health monitoring. On the other hand, the assistant robots for rehabilitation represent in the form of rollators [12], and smart wheelchairs [13] are deployed to assist with functional deficiencies and basic daily activities in both indoor and outdoor contexts.

Acknowledging the spatial limitation and pre-assigned roles in existing assistive robot applications, our research aimed to explore the novelty by investigating whether a zoomorphic mobile robot, Spot, originally developed for industrial purposes, could serve as a socially assistive robot to engage and motivate older adults in participating in outdoor physical activities. Co-design, often used interchangeably with Participatory Design, is a Human-Centered Design approach involving stakeholders throughout the design process to improve users' acceptance and the usability of the technological approach [2], [3], [4]. Recent studies suggested that incorporating co-design activities into research with older adults can result benefits of fostering mutual learning, compensating for their lack of direct robot interaction experience, and ensuring the requirements and capabilities are thoroughly considered [2], [14]. Our research is a participatory design study that consists of three phases, namely, the co-design workshop, the conceptual design, and the field study. This research is a qualitative study that collects data through contextual observations and semi-structured group interviews. Considering the zoomorphic mobile robot, Spot, is not common among the research in the field of human-robot interaction (HRI), the goal of the research is to investigate older adults' perceptions and the approach for delivering motivational robot-assisted physical activities. We formulated the following research questions:

RQ1: What are the older adults' perceptions of the assistive zoomorphic robot in physical activities?

RQ2: How can the assistive zoomorphic robot deliver motivational physical activities for older adults, from the viewpoint of the robot's A) roles, B) interactive behaviors, and C) characteristics?

II. Related Work

A. *Assistive Robots in Eldercare*

Robots have emerged as a form of assistive technology to promote physically active lifestyles and social interactions [15], [16], [17]. Assistive robots refer to technologies directed at assisting older adults in a variety of tasks [18]. In the wellness context of eldercare, the tasks of assistive robots include, for example, the support of mobility, initiating social interaction, and coping with isolation and loneliness [19]. According to Broekens et al. [20], there are two types of assistive robots in eldercare, namely, rehabilitation robots and social robots. The assistive robots for rehabilitation are featured as physical assistive devices, on the other hand, the assistive social robots are perceived as social entities equipped with communication capacities. Wu et al. [17] further explained assistive social robots in eldercare can be categorized as (1) animal-like companionship robots in enhancing psychological well-being, and (2) service-type

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robots in supporting and monitoring the safety of household activities.

Regular physical activity contributes positively to the well-being of older adults from disease prevention to the ability of independent living [2]. Considering older adults are liable for leading sedentary lifestyles, assistive robots have been introduced as a solution to maintaining mobility and quality of life [1], [5], [6]. Robotic walking assistants such as smart rollators and wheelchairs are equipped with distant sensors and obstacle detection algorithms to ensure safe navigation in both indoor and outdoor environments [22]. This type of assistive robot offers task-oriented interactions regarding physical mobility. Some walking assistant robots, i.e., Flo and Pearl [22], [23], developed for nursing homes, include touch-sensitive displays to adapt the emotional design in human-robot interactions. Another smart walker, AGoRA, includes a control strategy that responds based on the adaptation of users' behavior [24]. These studies demonstrate that assistive robots for rehabilitation incorporated multimodal functionalities in providing ambulatory and cognitive assistance [21].

Social robots with animal-like appearances are designed with zoomorphic embodiments [25]. Coates et al. [26] explained the term zoomorphic refers to the design that reflects animalistic-inspired qualities onto non-animal related objects. In the field of artificial intelligence, embodiment refers to the bodily presence of a robot to carry out physical interactions [27]. Some examples of zoomorphic social robots employed in the research of eldercare include Aibo, Paro, and iCat [20]. Related studies have shown that older adults tend to have positive perceptions of zoomorphic robots, which resemble a more intuitive and emotionally appealing interaction [28]. Spot robot, developed by Boston Dynamics is a zoomorphic mobile robot developed to perform tasks that are too dangerous or difficult for humans, e.g., inspecting construction sites and providing surveillance in factories. It is equipped with camera sensors to conduct environment mapping and obstacle avoidance. Recent research has employed the Spot robot and its human operator in guiding visually impaired people to walk along a designated outdoor route, which had positive results on the close partnership and trust between the participants, researcher, and the robot [29]. Considering the robust mobility and zoomorphic metaphor of the Spot robot, our research aimed to investigate older adults' perceptions of integrating the Spot robot as a walking guide in the outdoor environment, which relates to RQ1.

B. *Human-Robot Interaction with Older Adults: The Roles, Interactive Behaviors, and Perceived Characteristics of Assistive Robots*

Assistive robots have various roles in eldercare, including supporting the tasks of healthcare professionals, enhancing physical and psychological well-being, and providing companionship for older adults [30]. Ihamäki and Heljakka [31] found out that the robot dog, Golden Pup, has been perceived as a companion in activating social and emotional experiences of intergenerational activities between older adults and preschoolers. A review from Khosravi et al. [32] shows the application of therapy robots (e.g., the seal Paro and dog Aibo robots), telepresence robots, and robot walking support are effective in improving psychological well-being and reducing the feeling of loneliness for older adults. However, the role and tasks of assistive robots are mainly defined by researchers and healthcare professionals. Our research is a participatory design study that invited older adults as active collaborators throughout the research process for understanding their preferred physical activities and perceived roles of the assistive robot, Spot, which relates to RQ2A.

Current interactive behaviors of socially assistive robots encompass various emotional and persuasive strategies to enhance the engagement of older adults [33]. Robinson and Nejat [33] highlighted the existing challenges in adapting robot behavioral strategies to meet the expectations and ensure adherence of older adults. Motivation is a fundamental tool in establishing adherence and in promoting behavior change [34]. Related research has implemented assistive robots as social agents to enhance participants' engagement and motivation. The upper-torso humanoid robot, Bandit, was used as an encourager to perform mild physical exercises and custom-designed games by executing a series of social cues such as pointing, prompting, playing music, etc. [35]. In the study of Kidd et al. [36], the seal robot, Paro was effective in serving as a catalyst for social interaction between older adults through its haptic interaction, physical movements, and vocal utterances. Our research aims to understand whether the Spot robot can serve as a social agent in delivering motivational physical activities. Additionally, we are interested in exploring the interactive behaviors that occur between older adults and the Spot robot, which addresses RQ2B.

As assistive robotics continues to evolve, there are ongoing discussions of whether they will serve as the replacement for human caregivers [37]. Despite a widely held background belief that assistive robots are unable to offer the same level of healthcare as humans, these discussions have influenced how users perceive their implementation [37]. Langer and Levy-Tzedek [38] mentioned the implementation of assistive robot depend on both technological improvements and the acceptance from users in social environments. Langer and Levy-Tzedek [38] further suggested socially assistive robots used in rehabilitation should exhibit (1) trustworthiness, (2) empathy, (3) behavioral adaptation, and (4) cultural sensitivity. Our research expects to acknowledge the perceived characteristics of the Spot robot from older adults, which relates to RQ2C.

III. Research Procedure and Methodology

A. *Participants and Research Ethics*

Two groups of older adults from a Finnish nursing home participated in the study. The participants were aged between 75 to 103 years. The number of participants in the co-design workshop and field study was eight (one male and seven females) and seven (one male and six females), respectively. Three participants decided to discontinue their participation during the co-design workshop. In the field study, two other older adults from the nursing home agreed to participate. Hence, five participants were identical in both research phases, and they may possess higher initiative and involvement in outdoor physical activities assisted by the Spot robot. The participants had a wide variety in their ability of social activities, memory, and physical skills. However, they all possessed adequate cognitive levels to provide consent for participation and understand the given tasks.

The research was conducted with strict ethical and data security considerations in accordance with General Data Protection Regulation (GDPR). One week in advance of starting the research, the participants were provided with an informed consent form and a privacy notice form. The participants had the chance to ask questions from the researchers before signing the consent. Participation was voluntary, and only the ones who signed the consent took part in the study. The participants reserved the right to withdraw from the study without any consequences. Identifiable information was not collected from the participants, all the data were anonymized and were not linked to any single participant. The research presented findings obtained from the whole group. All the research activities involved participants have proceeded under the supervision and assistance of the responsible healthcare professionals at the nursing home. Finally, the research does not report any health issues that appeared during the study.

B. Robots Used in the Study

Spot robot (Figure 1), developed by Boston Dynamics[2], is a zoomorphic robot that has the compact mobility to navigate around a wide range of terrains. It is equipped with camera sensors to conduct 3D mapping and obstacle avoidance in the operating environment. In this study, the Spot robot was operated by a researcher using its mobile application through a tablet. It aimed to ensure safety and initiate natural and responsive interactions with the participants.

Additionally, in the icebreaking activities of the co-design workshop, a humanoid social robot, Nao, developed by Aldebaran Robotics[3], was deployed to demonstrate HRI to older adults. Nao robot has been used to encourage communication and social interaction [15]. Considering the positive perceptions it has gained, our research integrated one Nao robot to introduce robotic technology to older adults with a gradual approach.

Figure 1. The Spot robot and its opearting mobile application used in the outdoor physical activities of the field study.

C. Research Phases

The research was carried out at a Finnish nursing home from September to October 2022. Three research phases were implemented as part of the participatory design study, namely the co-design workshop, the conceptual design, and the field study. This section reports the research goals and procedures in each phase.

Phase 1: Co-design workshop. The co-design workshop was conducted in September 2022 to introduce robotic technology to the participants with a gradual approach. The co-design workshop consisted of the tasks (1) ice-breaking activities and (2) group interviews to understand participants' preferred interaction and acceptability toward assistive robots. The first task of icebreaking activities involved the Nao robot in demonstrating warm-up exercises and Tai-Chi performance. In addition, some descriptive videos and images of the Spot robot were presented to introduce its functionalities and potential application areas. The second task of the group interviews aimed to gain insights into participants' prior experiences with assistive robots, as well as their perceptions of robot-assisted physical activities. The interview focused on gathering information regarding participants' limitations, suggestions, and preferred outdoor activities. The collected data was utilized in planning the implementation of the follow-up field study.

Phase 2: Conceptual design. Building upon the data collected from group interviews during the co-design workshop, we conducted a conceptual design phase to map out the outdoor physical activities that would be assisted by the Spot robot in the field study. The Spot robot will guide the participants walking through a certain route and stopping by three checkpoints to facilitate (1) deep breathing exercises, (2) upper body stretches, and (3) dance performances in the yard of the nursing home. Figure 2 presents the sketch of the conceptual design for the outdoor physical activities. The physical activities implemented at each checkpoint were ideated by the older adults who participated in the co-design workshop. Finally, the healthcare professionals from the nursing home have agreed upon the route and tasks to be performed during the outdoor physical activities, ensuring the execution will be safe and appropriate for older adults.

Figure 2. The sketch of the conceptual design for the outdoor physical activities assisted by the Spot robot in the field study.

Phase 3: Field study. The field study was carried out in October 2022 with the tasks of (1) outdoor physical activities (Figure 3) and (2) group interviews. Five out of seven participants carried out the 45 minutes outdoor physical activities altogether in a small group setting. Two other participants who later joined the study carried out the outdoor physical activities as a pair. After the outdoor walk, we performed the group interviews in an indoor meeting room with all the participants to comprehend their perceptions regarding the Spot robot and the outdoor physical activities.

[2] https://www.bostondynamics.com

[3] https://www.aldebaran.com/en

Figure 3. The outdoor physical activities assisted by the Spot robot.

D. Data Collection

This research is a qualitative study that collects data through contextual observations and semi-structured group interviews.

Contextual Observations. There are two observation phases in this research. The observation findings were recorded by hand-written notes. The first observation took place in the co-design workshop, focusing on participants' interests regarding robotic technologies. The observation inquiries included: How do older adults interact with the Nao robot? How do older adults react to the videos of Spot robot? What kinds of emotional reactions do the robots evoke in older adults? The first observation aimed to acknowledge the suitable approaches to integrating assistive robots into seniors' daily activities.

The second observation was performed in the field study. The observation inquiries included: How do older adults react to the behavior of the Spot robot? Does Spot robot encourage older adults in outdoor physical activities? How do the group settings benefit older adults in robot-assisted physical activities? The second observation focused on understanding participants' perceptions of this specific wellness context.

Semi-structured group interviews. The research conducted two group interviews with audio recordings. The first interview was carried out in the co-design workshop. It aimed to understand older adults' robot literacy, initial perceptions of the assistive robots, and preferred physical activities assisted by the Spot robot. The interview questions included: What is your general impression of the Nao and Spot robots? What kinds of physical activities would you prefer to do with the Spot robot? What kinds of requirements and limitations do you have when conducting robot-assisted physical activities?

The second interview was conducted in the field study. It concentrated on the participants' experience and reflection on robot-assisted physical activities. The interview questions include: What do you think about the Spot robot in assisting physical activities? How was your experience of robot-assisted physical activities? Do you have suggestions for robot-assisted activities in the future? The interviews tend to be exploratory, which included open-ended questions to encourage insightful feedback from the participants.

E. Data Analysis

The affinity diagram is used to conduct thematic analyses in organizing a large amount of qualitative data from field studies [39]. The research utilized the affinity diagram technique to assort qualitative data collected from observations and interviews. Both data were assorted as affinity notes. The findings from the co-design workshop and the field study were each represented as separate affinity diagrams. The findings from the co-design workshop were arranged into four categories: (1) older adults' preferred outdoor activities, (2) older adults' attitude about the robot-assisted activities, (3) older adults' physical limitations, and (4) solutions to older adults' physical limitations. On the other hand, the findings from the field study were organized into six categories: (1) older adults' perceptions before the robot-assisted activities, (2) older adults' perceptions after the robot-assisted activities, (3) older adults' perceptions toward assistive robots, (4) older adults' perceptions toward the Spot robot, (5) older adults' ideations of different implementation approaches of wellness robots, and (6) what older adults' have learned from the robot-assisted activities. All the quotes from participants included in this article have been translated from Finnish into English.

IV. Findings

A. Older Adults' Perceptions Towards Assistive Robots and Robot-Assisted Physical Activities

Five out of eight participants developed interests and positive attitudes toward the robot-assisted physical activities performed by Nao and Spot robots, throughout the interaction. In the co-design workshop, some technical issues of the Nao robot, i.e., the low volume and English as spoken language resulted in unclarity in communicating with older adults. Furthermore, the participants did not fully understand the capability of the Spot robot as it was introduced through videos and images in the first phase. However, more than half of the participants demonstrated a more positive attitude after engaging in physical interactions with the robots, e.g., participants were attracted to the Nao robot by its humanoid appearance and the Spot robot by its natural and agile movements. One participant who did not participate in the co-design workshop was surprised by the non-humanoid appearance of the Spot robot at first, but the feeling faded away as soon as the interaction started. After the field study, participants gave positive feedback about engaging a robot companion in their physical exercise routine: *"This was much better than our daily walk, we did exercises on the way, and it was nice to see a machine can carry out various movements."* (P2). Two participants took pictures with the Spot robot to share with their families, indicating the enjoyment and excitement they experienced: *"We finally met the robot we are interested in!"* (P6). In addition, participants exhibited a strong sense of curiosity regarding the capability of the Spot robot, thus, some inquiries were addressed during the interaction: *"Does the robot climb stairs?"* (P1), *"Does the robot jump?"* (P2), and *"How can the robot understand our command?"* (P4). These inquiries from the participants and their active engagement demonstrated the enhanced robot literacy they have had throughout the robot-assisted physical activities. They even reflected on their perceptions of the development of robotic technology by saying *"No one is as wise as the engineer, who put a lot of effort into making the machine move naturally."* (P4).

B. Roles, Interactions, and Characteristics of the Spot Robot

The Spot robot was perceived as a popular *"Pet"* by older adults and healthcare professionals during the outdoor physical activities. Participants pointed out that the robot resembles the look of a *"Dog"* and a *"Grasshopper"*. The majority of the participants (five out of seven) did not perceive robots as a substitute for professionals, considering human operators are necessary to ensure safety and address individual needs. However, two participants who did not participate in the co-design workshop remained skeptical about the implementation of robots in the wellness context of eldercare.

Throughout the field study, participants showed great curiosity about the Spot robot and motivation to participate in the outdoor physical activities. The Spot robot had a positive character which attracted the attention of other older adults at the nursing home. Two roles for the Spot robot were recognized, namely the **encourager** for older adults and the **wellness assistant** for healthcare professionals.

Encourager. One senior mentioned: *"The robot made us walk further than we normally do."* (P7). Frequent interaction between older adults was observed, including discussions about the functionality of the robot and their perspectives on integrating robots in wellness contexts. It indicated the Spot robot was effective in encouraging seniors to achieve their exercise goals, as well as fostering communication and a lively atmosphere during the outdoor physical activities. In the group interview of the field study, participants further presented other ideas for integrating the Spot robot as a walking guide. One participant suggested *"The robot can wait outside of my apartment at a specific time to initiate a daily walk,"* (P4). The participant further explained *"And the robot should be persistent in asking me to complete the task."* (P4).

Wellness assistant. One participant suggested the Spot robot can collaborate with healthcare professionals in everyday tasks: *"The robot can deliver medicines; circulate between us to ensure we take the correct medicines or remind us to do it."* (P4). Another participant agreed to the idea by making a humorous comment *"And the robot could hit on someone's back if we took the wrong medicine."* (P3). One participant further stressed the practicalities of integrating the robot into the nursing home: *"However, it is important to have people supporting on the side in case the robot cannot fulfill the task."* (P2), which again highlighted the preferred role of the robot to be an assistant, rather than a substitute of human caregivers.

Both **physical** and **verbal interactions** from participants were observed in the outdoor physical activities with the Spot robot. The physical interaction was shown frequently during and after the dancing performance of the Spot robot. Participants reacted to the dance by clapping their hands, mimicking the bowing movements, and greeting the robot by waving and petting. The physical interaction was accompanied by verbal communication, for instance, participants gave the commands of *"Stand"*, *"Sit"*, and *"Dance"* to the Spot robot. When the robot accomplished the given tasks, participants rewarded it by saying "*Good boy*" as they were interacting with a pet. The proactive physical and verbal interactions initiated by the participants demonstrated they have developed social bonds with the Spot robot.

The perceived characteristics of the Spot robot from older adults were **obedience** and **friendliness.** We observed that participants were motivated to walk alongside the Spot robot. They showed patience while waiting for it to lead the route and proactively switched positions to walk beside it. Some participants engaged in the discussion about the gender of the Spot robot: "*She is like a girl, so lovely; No, he is as active as a boy.*" These friendly behaviors and comments from participants validated the positive experience they have gained from the robot-assisted physical activities. Three out of seven participants indicated the hands-on experience to control the robot was missing in this study: *"I can't say if the robot is easy to use because I didn't try out the operation."* (P5). However, they gave positive affirmations about the activities such as *"The robot can be useless for me, but it was interesting, I am looking forward to the continuation."* (P2) and *"It was so nice to see such advanced things, it's the future instead of a big miracle."* (P4).

V. Discussion

A. Older Adults' perceptions of Robot-Assisted Physical Activities

Throughout the co-design workshop and field study, participants demonstrated an improved perspective toward robot-assistive physical activities over the course of interaction. In the co-design workshop, almost half of the participants (three out of eight) decided to withdraw their participation after the icebreaking activities. The older adults' unfamiliarity with robotic technology and the language barrier were the obstacles that prevented fluent interaction with the Nao robot. In addition, we introduced the Spot robot through videos and images, which did not communicate thoroughly about its functionalities. However, participants were attracted to the physical movements of the Nao robot during the Tai Chi performance and mentioned they are fond of its humanoid appearance. Additionally, participants demonstrated positive perceptions of the assistive robot, Spot, after the field study. Participants mentioned during the interview in the field study *"I felt relaxed, and it was fun."* (P1). *"The robot was not scary, as we have seen the picture of it."* (P4). The findings demonstrated that gradually integrating assistive robots into the daily activities of older adults can be a good approach, as they become familiar with what to expect. We discovered that the humanoid attributes of the Nao robot, which are familiar to older adults, allowed it to serve as a mediator in progressively introducing the novel robotic technology. During the interview in the field study, participants even brainstormed additional use cases for the Spot robot, e.g., serving as an encourager for older adults and a wellness assistant for healthcare professionals. One participant mentioned, *"I wonder how it would feel to walk on the main street with it (refers to the Spot robot)."* (P3). Another participant replied, *"You may end up in the 10 pm news."* (P4). These humorous discussions between the participants demonstrated the zoomorphic attribute of the Spot robot does resemble an intuitive and emotionally appealing interaction, as suggested in the study by Marchetti et al. [28]. Additionally, we observed an improvement on the robot literacy of older adults from their active engagement and reflection on human-robotic technology used in eldercare.

B. The Roles of the Spot Robot

In the field study, the Spot robot gained **high popularity** at the nursing home. Spot robot was able to **create a lively atmosphere** in the outdoor walk, which act as **a catalyst for social interaction between participants**, as found in the study of Kidd et al. [36]. Participants mentioned the Spot robot served as **an encourager** in motivating them to walk longer than they normally do, which demonstrates the motivational factors described by Robinson and Nejat [33]. Participants showed strong curiosity toward the Spot robot and motivation in conducting physical activity with it. They discussed the gender of the Spot robot and asked questions regarding its robust mobility. One participant mentioned Spot robot can be programmed to initiate regular daily walks *"I can take this one (refers to the Spot robot) to my corridor for notifying me to go for a walk."* (P4). The other participants suggested, *"It would be great if the robot has a feature of ignoring our comments such as staying indoors and insisting on going on for a walk."* (P5).

Participants suggested the Spot robot can serve as **a wellness assistant** for healthcare professionals in daily tasks, for instance, managing the distribution of medicines. Participants further mentioned the importance of having support from healthcare professionals while using the robot in case it failed to complete the given tasks. These suggestions on the potential tasks for the Spot robot strengthen the roles of robots to be as an assistive tool instead of a replacement for human caregivers, which corresponds with the insight mentioned by Laitinen et al. [37]. Another participant emphasized the idea by mentioning *"We don't like the direction where there are more robots than humans in care homes."* (P4).

C. The Interactive Behaviors Between the Spot Robot and Older Adults

We found out that the Spot robot served as a **social agent in developing bonds** and **encouraging natural interactions** with older adults. Although the Spot robot does not support verbal communication, both **physical and verbal interactions** initiated by the participants were observed. As the Spot robot was controlled by an operator, it adapted to participants' behaviors and responded through physical movements, as discovered in the studies of Pineau et al. [22], Montemerlo et al. [23], and Sierra et al. [24]. Participants reacted and tried to catch the attention of the Spot robot by clapping their hands, mimicking its movements, and greeting it by waving and petting. Frequent positive feedback and comments such as *"Good boy"* from the participants were observed after the Spot robot responded to verbal commands, e.g., *"Stand"*, *"Sit"*, and *"Dance"*. Participants showed great enthusiasm while interacting with the Spot robot. The implementation of an industrial mobile robot in assisting physical activities for older adults has helped to improve the psychological well-being of participants as other social robots developed for nursing homes, which was presented in the study by Khosravi et al. [32].

D. The Characteristics of the Spot robot

The perceived characteristics of the Spot robot by participants were **obedience** and **friendliness**. We observed that participants were motivated to walk alongside the Spot robot. They showed patience while waiting for it to lead the route and proactively switched positions to walk beside it: *"I gave a little patting for it as well. It wasn't scary at all."* (P2). These comments from participants demonstrate the companionship they have received from the robot-assisted physical activities, as found in the study by Ihamäki and Heljakka [31]. However, three out of seven participants mentioned it was difficult to comprehend the usability of the Spot robot as they did not operate themselves. Although hands-on experience for older adults in operating the Spot robot was lacking in the study. Most participants remained positive toward this experience and expressed their excitement about the continuation. Their comments showed that the Spot robot has an appealing personality which is inviting for older adults to interact with it. The robot-assisted physical activities fostered participants' inquisitiveness and open mindset to engage in different types of interactions with the Spot robot.

E. Design Implications for Wellness Robots in Eldercare

Based on our findings, we concluded a set of four design implications for integrating wellness robots in eldercare. This list expects to contribute to the field of HRI by providing constructive considerations to improve and support the implementation of wellness robots for older adults.

1. **Motivate physical activities through robotic physical embodiment.** Our research observed the physical embodiment of the Spot robot encourages social interactions between participants and inspires participants to ideate various approaches of integrating the Spot robot in their daily activities. Robots have a strong novelty effect that can wear off over the course of interaction. To encourage physical activities with wellness robots, it is advisable to utilize physical embodiment as a motivational factor to better engage users, both in individual and group settings.

2. **Robots assist healthcare professionals instead of replacing them.** One of the major findings from this research indicated that older adults are opposed to the idea of robots substituting human caregivers, as found in the study of Laitinen et al. [36]. Older adults can develop positive perceptions toward wellness robots under short-term interactions. However, it does not represent the same level of trust that exists in human-human interaction. On the other hand, older adults had a positive attitude about using robots as assistive tools for healthcare professionals.

3. **Introduce robot literacy through interactions.** To promote a deeper understanding of how robotic solutions can be implemented in eldercare, it is advisable for wellness robots to demonstrate robot literacy during interactions with older adults. Robot literacy refers to the knowledge, skills, and understandings required to implement robotic solutions [40]. By serving as an entertaining element, wellness robots can help to promote the inclusiveness of robotic solutions in eldercare.

4. **Present robotic solutions with a gradual approach.** Older adults are one of the vulnerable populations whose needs and abilities tend to be excluded from the development of technology. To foster deeper acceptance of wellness robots among this population, it is advantageous to gradually introduce robotic solutions into their daily activities. For instance, initially introducing robots with a more familiar appearance, such as humanoid or pet-like robots, allows older adults to become acquainted with wellness robots at their own pace and comprehend the value and benefits of robot implementation.

F. Limitations

Our research was a short-term study that focused on the initial usage of the Spot robot at a Finnish nursing home.

Considering the strong novelty effect of robots that soon can wear off, long-term research is required to evaluate how long users' interest in a robot is maintained, or how can we maintain users' interest in a robot with different interaction approaches.

The research was a qualitative study that evaluate the integration of the Spot robot in a novel contextual setting. Quantitative data that utilizes statistical analysis to illustrate changes in user perceptions toward the assistive robot is absent from this study. There are two reasons that led to the exclusion of quantitative data. Firstly, the sample size in this study was small: the number of participants in the co-design workshop and the field study was eight and seven. Having a small sample size in this study may prevent the findings from being extrapolated. Secondly, almost half of the participants (three out of eight) decided to withdraw their participation from the study during the initial phase of the co-design workshop. Thus, the participants in both study phases were not identical. In another word, the five participants who continue to participate in the field study may have possessed higher initiative and involvement toward assistive robots and their implementation in eldercare, which may have effects on the findings.

VI. Conclusion

The goal of our research was to investigate the older adults' perceptions and the approaches for delivering motivational physical activities by integrating the zoomorphic mobile robot, Spot, as a walking guide in an outdoor environment of a Finnish nursing home. This research was a participatory design study conducted in three phases (1) co-design workshop (2) conceptual design and (3) field study. The research validates findings with qualitative data, i.e., contextual observations and semi-structured group interviews. The results reported the Spot robot, which was initially developed for industrial settings (e.g., construction sites and factories) has gained positive attitudes and high popularity among older adults and healthcare professionals. We found out that the Spot robot engaged participants in a series of natural social interactions. The increased perception of assistive robots and robot literacy of older adults were observed. The research contributes to the field of HRI by presenting a set of design implications for integrating wellness robots in eldercare.

Our future research will focus on involving target users as operators of assistive robots in wellness contexts. It aims to discover different approaches to integrating assistive robots into eldercare. We are also interested in the different roles and tasks of the robot and the types of interactions in which participants serve as the operator.

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