SISTER: SocIal robotS to support biopsychosocial frailTy

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Abstract

Frailty is a major modifiable risk factor affecting older adults' health, significantly increasing vulnerability to falls, hospitalization, cognitive decline, and mortality. Social Assistive Robots (SARs) have emerged as promising tools to support frail seniors, offering companionship, promoting healthy behaviors, and enhancing emotional well-being through empathic, personalized interaction. In this paper we present the Italian PNRR-funded SISTER project that investigates the use of SARs in domestic environments through a multicomponent intervention targeting nutrition, physical activity, cognitive training, and chronic disease management, and as group facilitators during counseling sessions. The project adopts a patient-centered approach to promote empowerment and participation, with the aim of assessing the feasibility, acceptability, and effectiveness of SARs in promoting active aging and providing personalized digital health strategies. A pilot study comparing outcomes in a robot-assisted group versus a control group will provide initial insights into the role of SARs in home-based care for frail elderly individuals.

Keywords

Frail older adults, social robotics, dialogue management, technology acceptance

1. Introduction

As people age, their quality of life and overall health can be significantly improved by managing certain risk factors, especially those that are reversible or preventable. One of the most critical of these is frailty, a condition that increases the risk of falls, disability, hospitalizations, cognitive decline, and even death [1]. Supporting frail older adults is essential, particularly when they live alone or have limited access to family support. In line with the "aging in place" paradigm, Social Assistive Robotics (SAR), a rapidly evolving field at the intersection of assistive and socially interactive robotics, offers a promising solution to support older adults in their own homes by serving as empathetic companions. SAR systems have already been successfully integrated into various projects, where robots have taken on roles ranging from facilitating recreational activities and providing physical and cognitive coaching to providing friendly reminders and supporting the treatment of anxiety and depression [2]. In most of the above mentioned projects, it has been demonstrated that the social robot provided a positive experience to users [3].

While SARs have proven effective in institutional settings (e.g. hospitals and residential care facilities), the Italian PNRR project called SISTER (SocIal robotS to support biopsychosocial frailTy of sEnioRs at home for promotion of active aging) aims to explore their impact in domestic environments. Within the SISTER framework, we designed a multicomponent intervention to be conveyed through a personal social robot, specifically directed at frail elderly individuals. Within the framework of patient-centred

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care, social robots represent a valuable tool for fostering patient empowerment, primarily by enhancing individuals' sense of agency and self-determination. They can also support social and emotional well-being, reducing anxiety, depressive symptoms and helping patients enhance social behavior, which is a key aspect of empowerment. Moreover, social robots can actively engage patients in their own care pathways, promoting a more participatory role [4]. In this regard, personalized social robots have demonstrated the ability to improve motivation, adherence, and sustained engagement in long-term therapeutic programs, thereby reinforcing the patient's active involvement in the treatment process. The selected participants will have to receive multimodal and customized programs as explained in FINGER study [5], encompassing physical exercises, nutritional plan based on a Mediterranean diet, cognitive training, counselling, reduction of metabolic and cardiovascular risk factors, adjustment of pharmacological therapy, and indications to grow social interactions that a multidisciplinary team will provide. At baseline, 3, 6, and 12 months, the cognitive status will be assessed by a psychologist, and information on health status, physical performance, lifestyle, demographic and socioeconomic factors, adherence to the intervention and the acceptability of the robot will be collected.

To this aim, we will study the feasibility of the presence of a SAR in the daily life of frail elderly people with critical social networks, in terms of empathy, such as willingness to undergo health promotion activities with attention to lifestyle, control of cardio, and cerebrovascular risk factors, and cognitive training. In addition, we will test the feasibility of this innovative device as a "collector" of data about seniors' daily life.

In the SISTER project, social robots are used in two different moments of the intervention:

i) in the context of counseling, participants in the project will be informed about the intervention and empowered with knowledge related to nutrition, physical activity, and overall well-being. The social robot Pepper will serve as a group mediator, facilitating not only the acquisition of knowledge but also fostering social interaction and connection among participants.
ii) as a personal companion to support the multicomponent intervention with the elderly at home. In this context, the social robot UBTECH Alpha Mini will be used.

A pilot study has been designed to investigate the impact of the presence of the robot on two groups of users: one equipped with the robot and a control group without it. The primary outcome of the pilot trial will be the feasibility of the multimodal intervention expressed in terms of retention rate and overall adherence to the intervention, and, further, the acceptability of the social robot in the intervention arm with the robot, and its potential as an innovative tool to implement personalized digital-health strategies.

2. Social robot in the nursing home

The primary goal of SAR systems is to provide non-physical assistance through social interaction, thereby promoting user engagement, motivation, participation, and learning. Feil-Seifer et al. [6] defined SAR as a category of robots capable of assisting individuals in rehabilitation, education, or emotional support by means of verbal, gestural, or behavioural communication. In this context, the integration of games and playful activities into social robots has proven to be an effective strategy for encouraging active user participation, enhancing engagement, and lowering technological barriers [7]. This approach is particularly beneficial for elderly users, children, or individuals with cognitive impairments, where play has shown positive effects both in terms of motivation and cognitive stimulation [8, 9].

The effectiveness of games in promoting engagement has been further validated in public, unstructured environments. For example, De Simone et al. [10] describe a social robot framework based on the Pepper robot, deployed at public fairs and events. The system successfully combined empathetic behaviour, conversational abilities, and playful interaction. Experimental results from these noisy and dynamic environments demonstrated that incorporating games significantly enhanced perceived engagement and user satisfaction, as well as improved the quality of conversational interactions. In this regard, humanoid robots such as *Pepper*[1] are particularly well-suited for engaging users [11], due to their cognitive and empathetic capabilities [12]. Therefore, integrating cognitive games into social robots represents a promising direction for improving user experience. In light of these considerations, within the SISTER project we have integrated gaming capabilities, such as *Rock, Paper, Scissors*[2] and *Connect Four* [3] into the MIVIA-Bot framework [10], reporting positive feedback from real-world deployments.

Figure 1: MIVIABot interacting with a person by means of the BrainHQ cognitive training exercises via Pepper's tablet interface (left) and with a lot of people during public events (right).

Notably, for elderly individuals the use of games designed to stimulate cognitive functions can be especially beneficial. Platforms like BrainHQ [4], which are grounded in decades of research on neuroplasticity, are well-suited for this purpose. In fact, developed by Posit Science, BrainHQ offers a personalized and adaptive training experience targeting cognitive domains such as attention, memory, processing speed, visuo-spatial reasoning, and mental flexibility. The platform, accessible via web (Figure 1), and mobile applications, is based on validated cognitive paradigms and has demonstrated efficacy in clinical, educational, and preventive settings. Clinical studies have shown measurable improvements in memory and processing speed, as well as real-world benefits, such as reduced accident risk among older adults [13]. This is why we decided to integrate BrainHQ into the proposed social robotics platform, aligning with the overarching objective of combining validated cognitive training methodologies with the motivational and relational advantages intrinsic to social robots. In this configuration, *Pepper* acts as an interactive intermediary between the user and the cognitive training platform, delivering voice-based instructions, dynamically adapting its behaviour to the user's cognitive state, and providing encouragement when signs of fatigue or difficulty are detected. Consequently, the robot assumes an active and supportive role, not merely as a technical interface, but as a socially engaging partner, thereby enhancing sustained user participation and maximizing the effectiveness of the cognitive intervention.

Beyond game-based interactions, the MIVIA-Bot is also capable of engaging in meaningful dialogue with users [14]. An important enhancement to its assistive capabilities is the integration of Large Language Models (LLMs) as knowledge sources to support question answering, particularly in health-related domains. Today, LLMs are widely employed in Question Answering (QA) tasks and can be effectively embedded in social robots to guide users in making informed dietary choices. This integration can serve as a tool to promote healthy nutrition by providing context-aware, personalized advice through natural language conversation [5].

The preliminary tests, conducted inside the University of Salerno using a 5-point Likert scale survey, show the effectiveness of the proposed approach. The results, illustrated in Figure 2, demonstrate strong user acceptance, with participants evaluating both the gaming experience with *Pepper* and the BrainHQ cognitive training, as well as the robot's conversational capabilities on nutrition-related topics, extremely positively, yielding ratings that are consistently close to the maximum value of 5.

[1]https://aldebaran.com/en/pepper/
[2]https://www.youtube.com/watch?v=_f6-o_Y86Wo
[3]https://www.youtube.com/watch?v=mZTrIPAC2I0
[4]https://v4.brainhq.com/
[5]https://www.youtube.com/watch?v=y1RDHbcGdjs

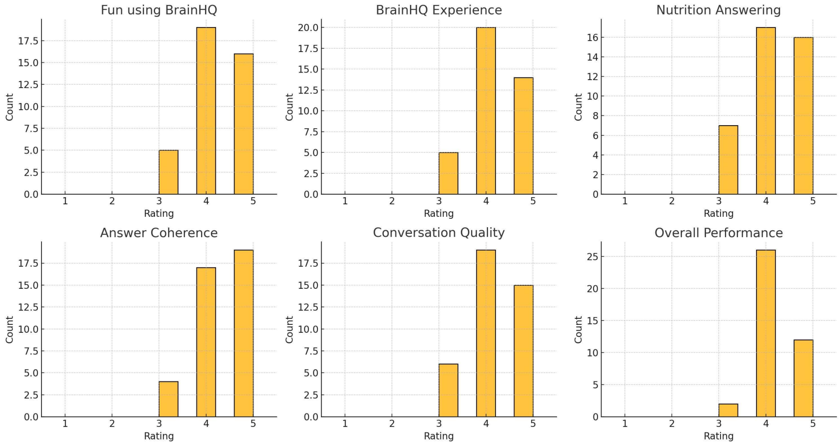


Figure 2: Histograms showing the distribution of user ratings for key questions related to the interaction with *Pepper* and the BrainHQ platform. The plots reveal a pronounced positive bias for most items, particularly in relation to overall system performance and the BrainHQ experience. In contrast, questions concerning answer coherence and conversational quality exhibit a slightly broader distribution of responses, suggesting greater variability in user perception.

3. Social robot at home with patients

Introducing social robots at home requires a careful design of their dialogue capabilities and service provision. In this context, personal robots, with their ability to adapt interactions based on user preferences and behaviours, play a crucial role in improving the well-being and participation of elderly individuals [15].

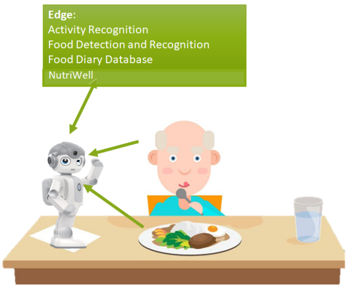
To this end, we developed the modular architecture of *Pixie*, which empowers the robot to act as a companion that gradually learns the preferences, interests, and actions of its assisted user and adapts its behaviour, enabling conversation and execution services by recognizing and answering voice inputs for an intuitive and easy interaction. Even if the proposed architecture can be used with several types of social robots, in the context of SISTER we propose its integration with a human-like social robot, UBTECH Alpha Mini [6].

Leveraging the possibility of customizing Alpha Mini's capabilities using its Software Development Kit (SDK), we designed and implemented a modular architecture which endows the robot with its behaviour, enabling conversation by recognizing and answering to voice commands for an intuitive and easy interaction. Although Alpha Mini's built-in software already embeds some of these features, we decided to adopt a custom architecture built from scratch to improve control over the robot's abilities. In this way, in the future, we could add or extend easily its functionalities and port the architecture on other robots.

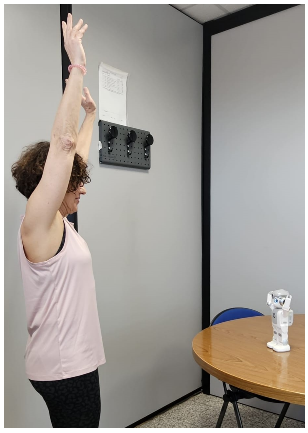
Within the architecture, we integrated a dialogue manager, offering both chit-chat conversations, designed to provide engaging companionship, and task-oriented dialogues, aimed at assisting elderly individuals with specific daily activities. At the core of the dialogue manager lies the process of intent recognition, which is essential for understanding the user's objective during each conversational exchange. It allows the system to produce relevant and meaningful responses, tailored to the user's expectations, whether the interaction is casual or focused on completing a specific task. To manage dynamic exchanges, a LLM is employed, specifically *Llama 3.1 70B instruct-turbo*. This model was selected after rigorous testing and comparative evaluation against other models available on the platform.

At present we developed services for two of the main intervention foreseen by the project: nutrition and physical activities. In [16], Pixie has been utilized as a companion during mealtimes, creating a more pleasant and socially fulfilling dining experience and at the same time providing useful insights on nutrition (Figure 3a). Moreover, using the motor capabilities of the robot, we developed an AI-based

[6]UBTECH Alpha Mini https://www.ubtrobot.com/en/consumer/humanoidRobots/alphaSeries/AlphaMini



(a) Pixie as a companion during meals



(b) Pixie guiding a physical exercise

Figure 3: Examples of Pixie in use.

system to explain and demonstrate exercises thus becoming a valuable tool for promoting physical activity, particularly in the home environment (Figure 3b). In [17] the robot not only encourages physical activity but also ensures that exercises are performed safely, making it an innovative tool for promoting both physical and mental well-being.

4. Conclusions and Future Work

The SISTER project represents an innovative approach to supporting frail older adults through Socially Assistive Robotics within a domestic context. By integrating a multicomponent intervention focused on physical, nutritional, and cognitive well-being, and by leveraging the empathic and interactive capabilities of social robots, the project aims to foster active ageing and improved quality of life.

These functionalities enhance the robot's role as a useful personal assistant, offering practical solutions to improve the user's daily routine and overall quality of life. The results of the pilot study will contribute to understanding the feasibility, acceptance, and impact of SARs in promoting biopsychosocial health in vulnerable populations, paving the way for personalized, human-centred digital health strategies.

Future works as part of the SISTER project include targeted evaluations within nursing homes for elderly individuals, with the aim of assessing the performance of the aforementioned system in its dual role as a nutritional assistant and entertainment companion. Additionally, evaluations will also be conducted in private homes to investigate the robot's acceptability in a domestic setting.

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Declaration on the use of Generative AI

During the preparation of this work, the authors used ChatGPT in order to: grammar and spelling check, paraphrase and reword. After using this service, the authors reviewed and edited the content as needed and takes full responsibility for the publication's content.

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