Co-Designing iCST with Social Robots for Long-Term in-Home Deployment for Persons with Dementia

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ABSTRACT

Individual cognitive stimulation therapy (iCST) is an effective therapeutic intervention that has been explored for aiding the cognitive ability of persons with dementia (PwDs). Despite its significant benefits, research evidence shows that it has been limited due to the burdens of caregivers, thus leading to low adherence. Therefore, this work explores the development of a social robot by co-designing with the key stakeholders for a 4-week in-home deployment in the homes of 10 PwDs. The system's effectiveness will be evaluated by assessing changes in the quality of life of the users and the caregiving burdens of their carers.

CCS CONCEPTS

• **Computer systems organization → Robotics**; • **Human-centered computing → Empirical studies in HCI**; **Interaction design process and methods**.

KEYWORDS

Robots for dementia, therapy robots, participatory design, cognitive stimulation therapy, in-home deployment

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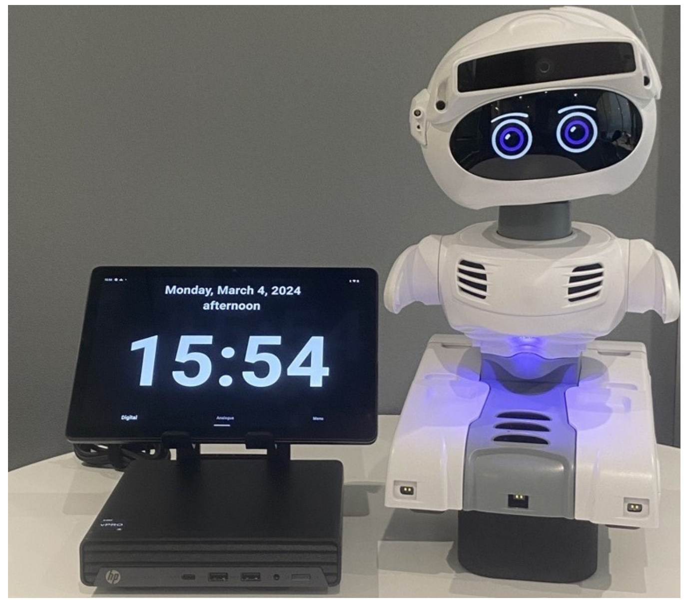

Figure 1: Setup consisting of a tablet display screen (showing the time and date), a mini-computer, and a misty robot.

1 INTRODUCTION

Dementia is an illness that leads to cognitive degeneration that inhibits persons from conducting their daily activities independently [6, 18]. Thus, they may require continuous monitoring and supervision. The number of persons with dementia (PwDs) almost doubles every 20 years [22]. In 2010, there were 35 million PwDs with a projected estimate of 65 and 113 million by 2030 and 2050 respectively. Estimates show that dementia care accounts for over $818 billion globally excluding informal care costs [22]. PwDs also represent the most significant proportion of residents in care homes [8, 15, 20]. Yet, most seniors prefer Ageing in Place (that is, remaining in their homes and communities as they grow older) to institutionalisation (that is, living in care homes or elderly facilities) [7, 31].

The lack of an existing cure for dementia [20] led psychologists to explore non-pharmacological approaches such as cognitive stimulation therapy (CST) [29, 34]. Traditional CST involves multiple sessions spanning for up to 45 minutes with two or three sessions weekly to engage groups of PwDs in activities that boost their cognition and quality of life [34]. CST has been well received due to its effectiveness in improving cognition and quality of life [34]. More recent work has seen the development of individualised CST (iCST) [35] to provide a person-centric intervention that is suited to the specific needs and preferences of a dementia patient. However, research on the use of iCST highlighted that the time-consuming nature of the sessions makes it difficult for caregivers to deliver them alongside other caregiving burdens [36]. Therefore, this work proposes the use of social robots for the delivery of iCST.

The goal of this research is to foster ageing in place (AiP) and iCST delivery for PwDs. To achieve this, this work seeks to address two key aspects of disorientation–detecting disorientation and preventing or reducing disorientation through cognitive stimulation activities for a long-term deployment. Previous robotics research has validated the use of social robots for aiding therapy sessions

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for PwDs. Such social robots have an embodiment and physical presence that can improve adherence than existing computerised alternatives. Hence, this work builds on existing work by gathering design requirements through consultation with stakeholders such as PwDs, formal and informal caregivers, care home administrators, academics and psychologists for an iterative co-design process on therapy robots for long-term in-home deployment. The final system will then be deployed in the homes of ten PwDs with mild to moderate dementia. The robot will be responsible for aiding daily cognitive stimulation in PwDs through pre-programmed activities to foster their independence to age in place. Disorientation detection will be aided through dialogues, interactions and in-home monitoring to then provide a suitable intervention for orientation in line with CST principles.

2 BACKGROUND

2.1 Reality Orientation

Reality orientation is a non-pharmacological approach that has been studied for over three decades for reducing the effects of disorientation that PwDs experience [11, 27]. It seeks to synchronise PwDs with time, place, and person by providing them with orientation information. This can be either in group sessions (typically 30 minutes) referred to as formal reality orientation or through 24/7 informal means. Informal reality orientation is provided by caregivers with significant burdens in addition to caregiving duties.

Most of the prior work on reality orientation was conducted by psychologists who focused mainly on formal reality orientation. However, the benefits can be short-lived, especially for persons with short-term memory challenges. This highlights the potential of in-home solutions such as with a social robot that can provide continuous interventions as needed by its user.

2.2 Cognitive Stimulation Therapy (CST)

Elements of reality orientation have since been adopted to create CST [2, 28] which gained widespread usage. CST is a non-pharmacological intervention that aids the cognition and quality of life of PwDs [28]. Traditional CST consists of up to 15 sessions delivered in up to 7 weeks consisting of 30-45-minute sessions [28]. Each session is delivered to a group of PwDs consisting of themes on various topics such as the calendar, holidays and anniversaries, family, daily life, identifying money, and reminiscence activities to elicit positive emotions from memories. The themed sessions are based on four phases–senses, remembering the memories, people and objects, and daily issues [28].

While CST has been proven to provide immense help to PwDs [1], PwDs do not have adequate access to it. This is due to the resource and time requirements for their delivery since a trained person is needed to facilitate the group sessions, highlighting a key limitation of traditional CST. Besides, some PwDs do not like the act of reminiscing with other PwDs since it involves them sharing some personal information and life history [33]. Yet there is a need for CST because of its associated benefits, especially during the winter months when PwDs can become isolated [36]. The group approach with the specialised training needed for CST and the necessity for personalisation were key factors that led to the development of iCST. iCST is a variant of CST that adopts a personalised approach delivered mainly by informal caregivers whereby the contents of the therapy are tailored to the preferences, interests and needs of the patient [21].

iCST was designed to bridge the gaps in the delivery of CST with significant benefits for the quality of life of PwDs. iCST includes person-centric activities consisting of up to 40 sessions on different themes [2]. Similarly to CST, iCST is limited in terms of its delivery as validated by the randomised control trial (RCT) which sought to highlight its potential benefits. The RCT which consisted of over 350 participants was limited by a lack of adherence [2]. Most participants completed less than the recommended number of sessions due to the caregivers having to combine the delivery of sessions with other caregiving duties [21, 24]. This underscores a possible void that a social robot could address.

2.3 Robotics for Dementia Therapy

Robots used in therapeutic contexts represent one of the most ubiquitous use cases of robotics for PwDs [14] such as those for CST. A significant number of cognitive stimulation studies with robots have been developed and tested but with healthy participants [10, 19], without consultations with the PwDs for the design. Hence, they adopted a producer-consumer design approach whereby a system is designed and then made available to the PwDs for an assessment to be conducted and tested within laboratory settings [10, 17]. However, deploying a social robot in homes for extended periods for iCST studies can significantly benefit both dementia and robotics research in various ways, as investigated in this study.

Similarly to psychology, most robotics for therapy studies have been group-based [9, 13, 26]. In [26], a multi-centre study was conducted and found a reduction in the carers' burdens but drew the conclusion from a sample size of five caregivers. The focus in [13] was to evaluate behavioural changes and found changes in dementia symptoms such as agitation and delusions in PwDs but recorded no changes in cognition similar to [9] which focused on emotion recognition during the sessions. There was little scope for personalisation in the group studies to address the core needs of each user thus neglecting the significant benefits of individualised care. Individual interventions can offer increased benefits than group interventions since they can be personalised to the interests, needs, and preferences of a person [36] however, they can be more costly. This provides an optimal spot for technology for the delivery of personalised interventions which can boost cognition and quality of life [16].

3 DESIGN CONSIDERATIONS

Social robots provide a cost-effective solution for CST-based orientation and activities with potential benefits to both PwDs and their caregivers by reducing their caregiving burdens. PwDs can benefit from a physical presence which can foster adherence more than non-embodied systems [5, 25]. In addition, a robot can provide more natural interactions with multi-modal capabilities in their homes which can help to support their independence by improving cognition, social and emotional engagements [32] better than computerised alternatives [3] with competency requirements. A robot can also be used to aid personalisation while performing daily therapy without the need for a caregiver.

A robot can deliver the iCST sessions without the need for a human facilitator. The robot can be programmed to perform the sessions at specific times based on the service user's preferences while ensuring consistency in the delivery. A robot's non-judgmental and lack of emotional responses are beneficial for eliminating or reducing the feelings of insecurity or discomfort that PwDs may feel if they are unable to answer a question correctly. Such social and psychological dynamics are inherent in human-to-human interactions where factors such as fear of judgment and self-image play a significant role. Therefore, PwDs can feel more at ease and be less concerned about their level of engagement during activities conducted by the robot.

3.1 Consultations with Stakeholders

Design requirements are being gathered through consultations with the relevant stakeholders such as dementia care professionals (DCPs). The DCPs consider this research work "important because most researchers ignore dementia patients". Thus far, our consultations have helped to create the design goals and design requirements for the system as presented in the subsequent sections.

3.2 Design Goals

While it is expected that the design requirements will change as the research progresses based on the consultations with the stakeholders, the core preliminary design goals are:

Autonomous: The system must be autonomous to ensure its operation does not need the presence of the research team for operation or the involvement of the PwDs such that it causes them distress by having to operate it.

Privacy-oriented: The system must preserve the user's privacy at all times, especially because it is in their home and collecting data from a vulnerable population. A vital consideration is to adopt a private cloud such that all information is stored in-house.

Effective: The delivery of interventions must be effective to achieve the intended aim.

Person-centric: The interactions delivered by the robot must be according to the preferences and needs of the PwDs.

Disorientation detection: The system must be able to detect when its user is disorientated to determine an appropriate intervention.

Orientation support: Upon detecting disorientation, the robot must be able to provide a suitable intervention to alleviate the disorientation.

iCST Administration: iCST sessions must be delivered by the robot based on the preferences of its user.

Connection to caregivers: The system must be able to contact the caregiver or family of the PwDs when needed to provide essential information regarding disorientation.

3.3 Detection of Disorientation

The detection of reality disorientation in this work is investigated mainly through the use of conversations and activities within the house. The robot utilises sensors within the home to detect disorientation before initiating an intervention. Likewise, it will be able to detect disorientation during its conversations with the PwDs such that it can determine if the session should continue or otherwise. Here, a language model will be utilised for the robot to track patterns of disorientation through the input speech from its users.

Orientation is administered using CST principles. For example, a user can experience night-time disorientation such that he or she wakes up at 2 am and thinks it is 2 pm, intending to conduct their daytime activity such as cooking lunch. Rather than seeking to change their reality which can cause distress, the robot will suggest that he or she take a nap or engage them in a different activity depending on their preference to ensure they do not leave their home at night assuming it is daytime. If this is ineffective, then it informs the caregiver to intervene to avoid exposing them to danger at night.

3.4 iCST

iCST is being explored with a social robot to deliver themed sessions regularly throughout the day. Here, instead of single long sessions running for up to 30 minutes, the sessions are divided into multiple parts. This is based on the findings that revealed that some carers and PwDs prefer shorter sessions [36], however, this is subject to further consultations with the stakeholders. The robot will be placed at a specific location within the home of a person living with dementia. The sessions are administered at specific times during the day after detecting the user's presence. A typical iCST session is as follows (subject to further modifications based on the participatory design requirements):

(1) Greetings.
(2) Play the user's favourite music to grab his or her attention.
(3) Provide orientation information (time, day, and weather).
(4) Introduce the session and verify if the user wishes to continue.
(5) Cognitive stimulation activity with themes such as food, using money, music, and reminiscence activities.
(6) Briefly ask the user for feedback on the session to collate their experiences and opinions.
(7) Thank the user and end the session.

4 DESIGN

4.1 Participatory Design

To achieve the design goals listed in section 3.2, an iterative system design is adopted as follows:

Design requirements: Interviews are being conducted with formal and informal caregivers, care administrators, psychologists, and most importantly with PwDs. This will involve 20 PwDs, 30 caregivers, 10 dementia experts and psychologists based on existing partnerships with care homes and independent living facilities. The interviews include open-ended questions to gather collective and individual experiences of disorientation, the current techniques used to aid orientation and their limitations.

The opinions of the stakeholders are also sought on the use of a social robot and how it can compensate for some of the limitations of the current approaches including their expectations of such a robot and their preferences for the interactions the robot provides. The personal insights of the PwDs are vital at this stage to ensure the design is suitable for their long-term use.

First prototype: The design requirements and insights gained in the consultations are being used to guide the development of the first prototype which is described in detail in section 4.2.
Design review: The first prototype will be reviewed with the relevant stakeholders to identify the shortcomings of the system. The review will include demonstrations of the working system to portray its capabilities. The interactions will be reviewed to ensure they can be effective for the intended use. All stakeholders will participate in CST sessions with the robot to examine how they feel about it and what changes are needed for the next design iteration.
Second prototype: A second prototype will be developed based on the review of the first prototype design. A final design will be constructed following consultations to review the second prototype.
Final review and design: A final review will be made to design the final system. The final review will involve demonstrations of the robot's interactions with tests involving the stakeholders to highlight any shortcomings of the design.
Initial Deployment: The final system will be deployed in the homes of three healthy adults for a week to conduct an in-depth test to ascertain the full operation of the system to detect problems which will then be fixed.
Final Deployment: The final system will be deployed in the homes of ten PwDs for a final assessment for four weeks. An evaluation of the system will then be conducted to assess its effectiveness for the intended aim.

The system and the design goals will be quantified using a set of metrics that include a Caregiver's Inventory Burden (to ascertain changes in carers' burdens), Quality of Life (QoL) assessment (to determine changes in PwD's QoL), MoCA (Montreal Cognitive Assessment) to detect changes in cognition and usability questionnaire to examine the ease of use.

4.2 Preliminary Design

Based on the consultations with the stakeholders, the initial system that is proposed consists of a mini-computer, tablet and Misty robot [30]. Misty was chosen because of its small size, relatively inexpensive cost, and design for human interaction with capabilities that are accessible to non-tech-savvy users. A tablet was integrated into the system to aid activities and provide an orientation board display to the users for time, place and date information similar to dementia memory clocks. The activities are synchronised between the tablet and the robot.

The robot's first interaction with its user involves a user registration whereby Misty seeks to collect relevant information about its user to consolidate the initial information gathered in the pre-deployment stage. A session begins with basic orientation information that includes the time and day as defined in the iCST program. The robot will then briefly introduce the content of the session to the user. This can be designed by the user with their caregiver or psychologist. The user will also have the option to choose a different session based on their preference.

In addition, the system includes a log system such that the completed activities and preferences of the user can be stored. This can increase the level of personalisation provided to the user by learning their interests and patterns of activities they engage in. For long-term use, personalisation must be core to the design of the system to ensure the impact of the novelty effect is significantly minimised. Future work can leverage machine learning techniques to learn patterns in the interactions and engagements that can enhance the personalisation provided by the robot.

The robot can interact with its users during the day with different cognitive stimulation activities based on their preferences. The robot interactions will include the delivery of cognitive stimulation sessions based on different themes and contents of iCST. Each cognitive stimulation session is conducted for 10 minutes with the option for a user to decide if they wish to end the session sooner based on his or her preference. Activities such as categorisation tasks, word association, and trivia quizzes are also included in line with iCST since PwDs may be more familiar with them [23]. It is intended that the activities will be done twice daily, early and late afternoon, depending on the time preference of the PwDs.

The robot will also be used for reminiscence activities such as displaying images of memories to improve their mood with research evidence also showing that it can improve some cognitive functions [12]. Life story reminiscence is used with the inclusion of images from the past. Music-related activities will also be incorporated for relaxation and increased mood. The activities will be delivered by the robot as designed by the user with a web portal.

4.2.1 Personalisation with a Web Portal. The system utilises a web portal to aid the personalisation of activities and the iCST sessions. This allows a caregiver or psychologist to co-design the weekly sessions with the PwDs. The web portal can be assessed in-house or remotely as needed. The duration and timing of the various activities can be set with some information on the progress made by the user displayed in the progress tracker. The portal also provides an avenue to gather sufficient information about the user such as their interests, hobbies and memories. Bugs and problems encountered with the system can also be reported on the portal for prompt changes, and feedback can be provided by the users.

4.3 Ethical Considerations

The design of robotics for vulnerable persons such as seniors who have been diagnosed with dementia as stated by the Diagnostic and Statistical Manual of Mental Disorders [4] requires a careful ethical design subject to approval by the relevant ethics committees. For PwDs, there is a need for a robot to regularly detect their level of lucidity to ensure they can adequately engage in a conversation or activity with the robot. The robot can suspend interactions when it detects that a PwD is not lucid enough to engage.

While the design seeks to address the needs of a broad target audience of older persons, the long-term deployment of social robots is not suitable for persons with severe dementia. Such a population can experience significant distress from having a robot in their home. Therefore, only persons with mild and moderate dementia are considered for this work to ensure they have enough capacity to interact with the robot and understand its intended purpose.

Furthermore, the intended use of a large language model (LLM) introduces an ethical concern. While LLMs offer immense potential for human-level dialogues for a social robot, they can often hallucinate. Hence, mitigation techniques such as context injection and retrieval-augmented generation RAG must be considered with other fine-tuning methods to mitigate such.

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