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A Musical Robot for People with Dementia

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Abstract

This doctoral research aims to enhance the Quality of Life (QoL) of People with Dementia (PwD) by developing a personalized musical robot to provide support through music and reminiscence activities. Our research is dedicated to creating and facilitating meaningful activities, while reducing agitation and improving PwD's mood. Key studies include the development of a music recommender system based on episodic memories, robotic assistance in daily activities through schedule-related music, and collaborative storytelling involving the PwD and their informal caregivers. These interventions are intended to support emotional regulation and communication. This PhD is part of the QoLEAD project, which integrates multidisciplinary research to bridge the gap between AI and warm care in dementia.

CCS Concepts

• **Human-centered computing** → **User studies**; *Collaborative interaction*.

Keywords

Robot; Music; People with Dementia; Storytelling; Music Recommendation; Memories; PhD

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Dementia encompasses various neurodegenerative diseases that impair cognitive functions, including Alzheimer's disease, frontotemporal dementia, vascular dementia, and Lewy body dementia. Currently affecting 55 million people worldwide, the number of People with Dementia (PwD) is expected to reach 150 million by 2050 [19]. While these diseases remain incurable, research efforts are dedicated to enhancing the Quality of Life (QoL) of PwD through diverse diagnostic techniques, drug development, and non-pharmacological interventions. QoL, in this context, encompasses a multidimensional evaluation of the individual's interaction with their environment and their ability to adapt to the perceived consequences of dementia [6].

In the early stages of dementia, symptoms such as reduced concentration, short-term memory lapses, and difficulties with complex

daily tasks are common. During this phase, PwD can often stay at home with the assistance of an informal caregiver, typically a family member or partner. As dementia progresses to mid and late stages, it begins to affect long-term memory, speech, and general mobility, necessitating care in professional facilities such as nursing homes. Caregivers, both informal and professional, are central to the well-being of PwD, participating in various therapies and often facing burden [15].

Among non-pharmacological interventions for PwD, Reminiscence Therapy (RT) and Music Therapy (MT) are prevalent. RT, which helps PwD recall past life experiences, has been shown to improve cognition, mood, and reduce depression symptoms [28]. In recent years, Reminiscence Therapy has been integrated through Music Therapy, substituting dialogue with musical stimuli to evoke memories. Additionally, MT is typically a one-on-one, active music activity, but can also involve group dancing and listening activities. For PwD, MT primarily targets depression and agitation, and generally offers less to no cognitive improvement over traditional RT [27].

Technology is now playing an increasingly major part in these therapies, ever more since the recent developments of Machine Learning and Large Language Models. During the last years following the COVID-19 pandemic, PwD have started to use online video calls more and more, which has led to the rise of online RT [1, 16]. RT has also been integrated through multimedia autobiographical storytelling, spanning audio [9], video [8] or other multimodal reconstitution of past life events. In the case of MT, the main improvements have been achieved in the use of virtual instruments [22] and the recent developments of music streaming platforms, which have democratized the use of personalized playlists [7]. Not only computer systems have been integrating RT, but Social Interactive Agents have also been one of the major improvements in Dementia Care, albeit still at research stage.

Since the late 2000s, social robots have been explored as tools to enhance the QoL of PwD by maintaining cognitive abilities, improving mood, and reducing agitation. These robots have been employed in various ways, including RT, cognitive stimulation, and monitoring PwD conditions [3]. Key functions of social robots in this context include:

- Social engagement and companionship
- Reminder Systems
- Promotion of Physical Activity

Robot Music Therapists have been part of assistive robotics research since its beginning, with regular improvements in their effectiveness and acceptance [10, 25, 30]. However, apart from companionship robots [18], many Socially Assistive Robots (SAR) have yet to demonstrate substantial benefits for cognition and depression in PwD [29], despite generally positive reception during interactions [31].

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Current challenges in dementia care technology focus on personalization and empowerment. Empowerment involves maintaining a sense of identity, choice, usefulness, and worth [26]. Person-centered care approaches, which personalize interventions to individuals rather than applying generalized solutions, are central to modern care strategies [14]. However, these approaches require detailed knowledge of the life of each PwD, making large-scale implementation difficult [23]. In this regard, new systems should be able to adapt their way of interacting to PwD, while being as manageable as possible for them. In the case of Reminiscence Therapy, one of the main solutions would be to use content generation, for example.

Another main challenge, in the case of robotics, is the robot's memory. While robots can include Large Language Models and benefit from the recent progress in this field, they still lack a full memory support, and do not take into account the full history of previous interactions, which is key to empathetic interactions [4].

These challenges and issues have led to consider the need to involve multidisciplinary research groups, to study the link between Dementia Care and Technology from the point of view of medicine, psychology, computer science and social robotics. The QoLEAD project, which this research is part of, aims to bridge the gap between warm care [11] and AI for PwD. It revolves around cooperation between AI, economy and politics experts as well as care professionals to provide improvements in dementia care. In this cooperative environment, our research goal is to investigate social robotics as a personalized therapeutic means through its connection with Music and Reminiscence Therapy. In this context, we do not focus on the way to design interventions, but on the possible positive effects of music to support the meaningful activities of PwD.

1 Research Objectives

Our research will focus on creating personalized human-robot interactions for PwD focusing on reducing agitation and improving mood through music. We can sort these interactions in different categories:

- Interactions helping remember past meaningful moments of life
- Interactions for supporting daily activities
- Interactions for creating new meaningful activities

In order to target these types of interactions, we will first build a music recommender system based on episodic memories, which stems from the fact that songs can help people remember specific episodic memories, and vice versa. Using this system, we will help PwD during stressful activities by playing music targeting specific episodic memories depending on their future schedule. This will be then combined with automated collaborative storytelling activities between PwD and their partners, in order to help to create meaningful activities and enhance communication.

We will thus answer to the following research questions:

- RQ1: Can we create links between specific episodic memories and songs to leverage a music recommendation system supporting emotion regulation?
- RQ2: Are music-evoked autobiographical memories

(MEAMs) capable of effectively regulating PwD's mood during robotic-assisted activities?

- RQ3: Can a personalized multimodal storytelling robot improve experienced communication between PwD and their informal caregivers?

2 Approach and Methods

2.1 Music Recommender System Based on Episodic Memories

The idea of a Music Recommender System Based on Episodic Memories for PwD stems from several considerations:

- 30% of popular songs in the reminiscence bump (songs remembered from childhood) are generally linked with an episodic memory [12]
- Songs in the reminiscence bump of PwD can involve specific episodic memories [2]
- Current Music Recommender systems [17] or datasets [5] have been able to link songs to specific episodic memories, and have shown that these links can have stronger effects on mood than other songs.

In the field of music-evoked autobiographical memories, songs are shown to elicit episodic memories. However current studies do not focus on recommending songs based on specific episodic memories. Current studies have also shown that linking memories to vibro-tactile patterns is possible [24] but this experiment has not been tried for songs.

Current Recommender systems use two types of recommendation:

- collaborative-filtering, which consists of looking at what other similar users have in their playlist and recommending one of their songs
- content-based filtering, which uses the song features for recommendations

Nowadays, hybrid systems (which combine both types of filtering) are the most popular. However, they do not take into account the targeted person and their history. This is why we will use a conversational agent approach for our system [13]. We will use song features (genre, era, and artist) as well as episodic memory features (people, places, and objects) to create links that will target specific moods (through their valence and arousal values). We will first let the user describe their memory, and associate artists to the place and person involved in the memory. Additionally, a local Large Language Model can define which artists can be recommended if the user does not have any association between a person (or a place) and an artist in mind. At a later time, the agent will propose songs depending on these artists and other memory features discussed earlier. The current framework for this recommendation system is described on figure 1. The current recommendation comprise 2 songs corresponding to the people involved in the memory, and 2 songs corresponding to the place. In each pair of songs, one is chosen with a congruent mood to what the memory evokes, and the second one is chosen randomly from the given artists in the interaction phase. In the current framework, a questionnaire is added after the recommendations to get feedback on the factors

that influence positively or negatively the association of songs to a memory.

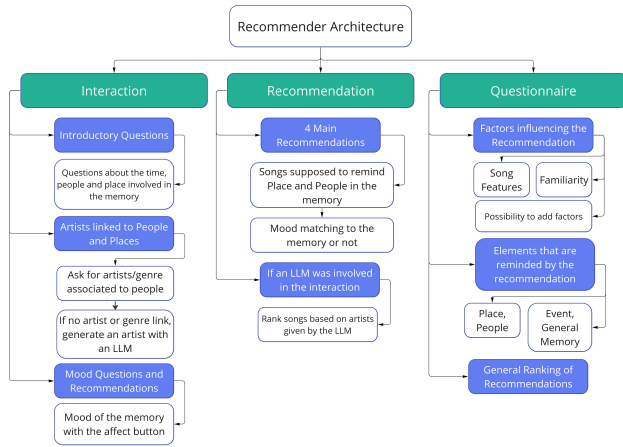


Figure 1: First Draft of the Music Recommender architecture

While this system might be efficient in the case that the user already has an idea of the artists that they would link to the memory elements, it is heavily dependent on the ability of the user to effectively link new songs to memories, which might lead to less efficiency for late stage PwD.

This system will first be tested in a mixed methods (qualitative and quantitative analysis) study, in which the main course of improvement will be defined. In a second study System and User critiquing will be added, and the system will be compared to [17]. It will be then used to create new types of interactions involving PwD.

2.2 Soothing PwD-Robot interactions through schedule-related songs

In the full-scale deployment of socially assistive robots (SARs) for People with Dementia (PwD), a primary focus, beyond reminder systems and task management, will be empowering PwD to manage their activities of daily living (ADLs) for as long as possible. However, due to agitation and stress associated with certain ADLs, PwD may eventually find it difficult to perform these activities. They may also experience significant stress when they are unable to perform as well as they desire (e.g., dropping objects, not understanding a task, etc). SAR systems must be capable of helping PwD calm down before, during, and after stressful ADLs. Therefore, this study will focus on creating soothing musical interactions with a robot.

While recent SAR approaches emphasize personalization, none have considered the daily schedules of PwD. Understanding the effects of specific future events on PwD could aid in soothing them. In this study, we will first discuss the interactions and activities PwD find meaningful, with the help of caregivers, and identify the people or situations that either agitate or calm them. We will then utilize the music recommender system developed in our initial study to select memories that are likely to be the most calming, based on the future schedules of PwD.

The system will use knowledge graphs to represent episodic memories, incorporating future scheduled activities and considering the emotional attachment to these memories for song selection. This memory module will employ a graph database to store and manage the knowledge graph, which will represent episodic memories involving places, people, and events.

A schedule module will track future activities, which can be entered by caregivers or the PwD themselves. It will calculate an importance score for each event based on recency, uniqueness, and positiveness.

An interaction module will manage recommendation discussions by asking PwD about their positive upcoming events and suggesting songs linked to these events. The robot will prompt the PwD to listen to a calming song linked to a future positive event before a potentially stressful daily activity. The system will adjust recommendations based on user feedback and the PwD's mood after each interaction. The algorithm will employ a notion similar to the definitions of relevancy and recency from [21] to rank the importance of each future scheduled event in achieving the desired calming mood. The system will also avoid repetitive song usage by reducing the relevance of a song after it has been used frequently.

Finally, a task assistance module will provide personalized encouragements during ADLs, reminding PwD of future positive events to calm and motivate them.

We will evaluate the framework through a real-life user study, measuring engagement and stress levels to validate the effectiveness of MEAMs in reducing agitation and enhancing the well-being of PwD during robot-assisted tasks.

This type of interaction will necessitate facial recognition of stress during the ADL, speech recognition and dialogue management, as well as an audio and visual interface for recommending songs.

Thus this study will focus on creating interactions that assist in performing daily activities. However, further efforts are needed to help PwD communicate effectively with their informal caregivers and maintain emotional bonds.

2.3 HRI for communication facilitation through generated multimodal storytelling

Maintaining communication and bonds is extremely important for the relationship between PwD and informal caregivers [20]. While digital storytelling has been tested on PwD and their caregivers, studies lack real-time creation of stories and multi-modalities [23]. Currently, there is a lack of knowledge on which modality of storytelling is the most efficient for PwD, and which would empower them to choose how they want to tell their autobiographic memories.

In this study, we will focus on letting PwD and their caregivers create interactive stories that will discuss episodic memories. They will be able to choose the modality they want to use (video, still images as a comic, written text) and will be able to edit it in real-time through a discussion with the robot. The memory chosen to create that discussion will be decided by the PwD and their caregivers before the interaction.

The storytelling will be mediated by the same robot as the previous study, which will discuss with the people involved and take into

account their recommendations on the way the memory should be portrayed. This study will be done with and without the presence of the robot, to check how much it would improve discussions. This system will be evaluated both in terms of preferred modalities for PwD and general communication improvements through a questionnaire measuring Experienced Communication in Dementia [20].

In an extension to this study, the implementation of music as a modality could be considered, to push the capabilities of the system further.

3 Current progress and future publications

3.1 Current progress

Currently, the music recommendation system has been developed and will be tested through an experiment involving 60 people of several age groups.

The framework for the soothing interactions module is under review as a workshop paper in the Robotics Science and Systems (RSS 2024) conference.

3.2 Publication Plan

There is currently a plan for a minimum of four papers. The Music Recommender system qualitative study may be published in the Conference on Human Factors in Computing Systems (CHI) 2025, the follow-up study may be published in the ACM RecSys Conference. For the soothing interactions, the current publication plan involves the ACM HRI conference. The Storytelling interactions would possibly be published in International Conference on Multimodal Interaction (ICMI). Additional publications could be done in Journals. Each paper would consist of a chapter of the final thesis. All of the mentioned conferences are indicative.

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