A Framework for Music-Evoked Autobiographical Memories in Robot-Assisted Tasks for People with Dementia

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***Abstract*—This paper introduces a framework that integrates Music-Evoked Autobiographical Memories (MEAMs) into robot-assisted tasks for people with dementia. The primary objective is to investigate how MEAMs can alleviate stress and enhance engagement during daily activities supported by robotic assistance. Our proposed system personalizes music recommendations by considering the emotional significance of future scheduled events and their connection to previous episodic memories. This personalization is further enhanced through a hybrid critiquing system, allowing individuals with dementia to provide feedback and refine the correlation between their episodic memories and the suggested songs.**

I. Introduction

Dementia encompasses a range of diseases that impair memory, cognition, and the ability to perform activities of daily living (ADLs). The global prevalence of dementia is rising, currently affecting 55 million people and is projected to reach 150 million by 2050 [34]. Various non-pharmacological interventions, such as Reminiscence Therapy (a type of psychotherapy that involves recalling past events), have shown value in mitigating cognitive and mood-related symptoms in People with Dementia (PwD) [12]. However, these therapies are limited in their ability to assist PwD with daily activities and to serve as reminders in the absence of caregivers, particularly for those in the early stages of dementia who remain at home. Advances in technology suggest that social-assistive robotics may offer a viable solution in these scenarios.

Social robots have been heavily investigated for their various applications for People with Dementia (PwD), ranging from companion robots like PARO [22] to reminder robots aiding ADLs [29]. These robots can alleviate caregiver burden and assist with cognition and agitation [9]. Their primary benefits include providing companionship and reducing agitation [23], which can be enhanced by incorporating music, known for its effectiveness in alleviating agitation and depression symptoms [41]. Consequently, integrating music into robot-assisted tasks could act as a stress reliever during ADLs, even if it does not directly address cognitive symptoms.

Current musical robot applications for PwD focus on cognitive enhancements through musical games [40] and are in most cases only employed as a feature among several in companion robots [16]. However, the impact of memories evoked by songs during robot-assisted tasks remains unexplored.

Recently, Music-Evoked Autobiographical Memories (MEAMs) have shown promise in therapeutic settings for PwD. MEAMs involve the retrieval of episodic or autobiographical memories triggered by music, either consciously or not [19]. The number of MEAMs and their frequency remain largely unaffected by dementia, although individuals with fronto-temporal dementia may experience fewer MEAMs [2]. The association between memories and songs enhances mood regulation and amplifies emotional responses [42]. Therefore, songs evoking memories have the potential to more effectively reduce agitation and stress in PwD compared to other liked songs [30].

This study aims to contribute to the broader objectives of personalization and empowerment [15] within the framework of warm-care [18].The goal is to endow social robots with the capabilitity to help PwD maintain their sense of identity and autonomy while performing daily activities with minimal physical assistance.

Thus, this study seeks to define a framework to be able to address the following question:

"Do MEAMs reduce stress and increase engagement during robot-assisted tasks for PwD?"

II. Related Works

A. Conversational Agents Music Recommendation Systems

Music recommendation systems often utilize conversational agents to create interactive user interfaces. Jin et al. [21] integrated critiquing from both the user and the agent in their interfaces, using multi-attribute utility theory (MAUT) [46] to enhance the critiquing process. They argue that hybrid critiquing for recommendation systems not only increases the diversity of recommended songs but also improve the overall user experience. Cai et al. [8] found that progressive system critiquing yields more diverse recommendations and reduces the number of user interactions compared to cascading system critiquing. Nair et al. [31] employed a conversational agent to analyze user emotions for song recommendations, highlighting the potential for further enhancement through techniques like facial emotion recognition. Overall, incorporating conversational agents and hybrid critiquing in music recommendation systems can improve personalization and user engagement and control over the system. However, building a similar

system using songs related to autobiographical memories would necessitate additional critiques beyond song features, for example memory elements (places, people or events).

B. Episodic Memory Representation in Computer Systems

Effective representation of episodic memories is crucial for utilizing MEAMs, especially when the goal is not only to play songs related to memories but to share them contextually with user feedback. The three main functions that are important in our case are the presence of a data structure to save memories, the consideration of elicited emotions of each episodic memory and the elicitation of a chosen memory at an appropriate time. Leolani [43] and the recommender system defined by Lim et al. [28] both use knowledge graphs based on the 5W and H questions (what, where, who, when, why, how). Another possible representation is defined by Derbinsky and Laird [10], who represent episodic memories as triples (context, content, and outcome). Dudzik et al. [11] introduced a framework for an artificial empathetic memory, tracking user memories and adding new ones in real-time, while considering associated emotions. Park et al. [35] suggests incorporating a notion of importance in their agent's memory. As memories related to unique life events are more vivid and elicit stronger emotional responses [4], this could be an appealing solution. Our proposed system combines these approaches by creating a knowledge graph based on the ontological elements of episodic memories, associating emotional pleasure and arousal. The description of previous systems compared to our approach is summarized in table I.

	Vossen et al. [43]	Lim et al. [28]	Dudzik et al. [11] (Frame-work)	Park et al. [35]	Proposed Frame-work
Data structure to save memories	**X**	**X**	**X**	**X**	**X**
Consideration of elicited emotions		**X**	**X**		**X**
Elicitation of a chosen memory at an appropriate time	By context		By emo-tion	By recency and impor-tance	By recency and impor-tance

TABLE I
COMPARISON OF OUR PROPOSED APPROACH WITH OTHER MEMORY BASED FRAMEWORKS

C. Social Assistive Robots for assisting PwD in ADLs

One important focus of research for increased engagement and motivation to perform activities is through robot coaches. This research topic emphasizes the importance of physical embodiment over virtual agents for enhancing motivation and engagement, and focuses on multimodal conversations. Spitale et al. [39] combined reinforcement learning with multi-modal features to improve feedback during well-being coaching sessions. Saravanan et al. [37] and Fasola and Matarić [13] utilized intrinsic motivation and goal-reaching conditions to drive agent feedback, providing stronger motivation to continue activities.

On the other hand, most social assistive robots designed for People with Dementia (PwD) focus on activity reminders and cognitive games [1], with a limited set of actions, intervening only when it is required [3]. Current applications aim to keep PwD engaged during activities [44], with recent research exploring robot implementation in long-term care facilities for late-stage dementia [3, 17, 5]. While engagement is generally high [36], issues such as fast speech can decrease understandability and post-activity engagement [26, 14]. This is why robot's speech speed should be considered, as well as the engagement both during and after the activity.

III. DESIGN RATIONALE

Our architecture follows Socio-Cognitive Engineering guidelines [38, 32], defined through claims, effects, and functions driving robot interactions. The key functions for our design and the proposed solutions are described in table II

Function	**Proposed Module**
The robot should support ADLs while allowing PwD to shape their activity.	Activity module (providing reminders during ADLs)
The robot should consider the PwD's schedule to choose future positive events to remind them of.	Schedule module (tracking future activities) Memory module (representing the PwD's episodic memories)
PwD should have control over song recommendations.	Interaction module (managing recommendation discussions)

TABLE II
MAPPING OF KEY FUNCTIONS TO SOLUTIONS IN OUR ARCHITECTURE

This system is designed for the purpose of increasing engagement and reducing stress during ADLs, while giving PwDs a sense of control and autonomy over their interactions with the robot. Before a potentially stressful daily activity, the PwD will be prompted to listen to a calming song linked to a future positive event. This event will be reminded throughout the robot-assisted activity. We will now detail each module of our implementation.

IV. PROPOSED ARCHITECTURE

The proposed architecture is illustrated in Figure 1. This section details the functions of each module within the system.

A. The Schedule Module

The Schedule Module manages the PwD's future events, which can be entered by caregivers (professional or not) or by the PwD themselves. Existing schedules can be partially imported automatically. For personalized recommendations, details such as people, time, place, and event descriptions are necessary. An a priori mood can be added to reflect the expected emotional state of the PwD for each event. Unique events are given higher importance scores compared to regular events.

The importance score is calculated using a method similar to Park et al. [35]:

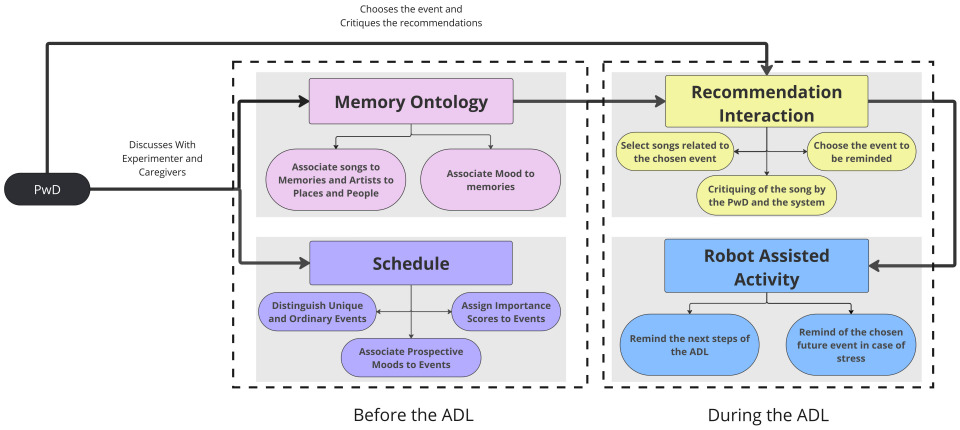

Fig. 1. Proposed Architecture

$$\begin{aligned}\text{Importance Score} = \alpha_1 \cdot \text{Recency} \\ + \alpha_2 \cdot \text{Uniqueness} \\ + \alpha_3 \cdot \text{Positiveness}\end{aligned} \tag{1}$$

Each value ranges from 0 to 1, and the weights α are currently set to 1, but they can be adapted depending on the PwD. Recency is a linear function peaking for the nearest events. Uniqueness is calculated as $1-p$, where p is the probability of the event occurring on any given day based on the entered schedule. Positiveness reflects the mood entered by the caregiver or PwD and is updated after each recommendation. This ensures that events that are imminent and unusual are preferred. For example, upcoming family visits will be valued more than daily meals or breaks, assuming the positiveness of the events is the same.

B. The Memory Module

The Memory Module utilizes a knowledge graph to represent episodic memories, focusing on places, people, and events. Figure 2 provides an example of a memory triplet involving a memory, a place and a person.

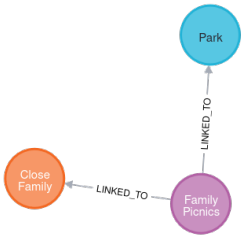

Fig. 2. Example of a triple memory/place/person in the ontology. In pink, the memory; in blue, the place; and in orange, the person. Here, the example memory is a picnic in the park with the PwD and their family

The memory graph includes elements such as songs linked to events and the mood associated with each event. This information can be filled in by the PwD or the caregiver by choosing life events that are already associated with songs. If the PwD and the Caregiver cannot provide any song related to specific life events, popular songs from when the PwD was between 15 to 25 years old [20] can be played to try to find which ones elicit MEAMs, and the mood felt while listening to them can be deduced through the use of the affect button [7].

C. Music Recommendation Interaction

The robot's memory loads episodic memories and scheduled events, extracting relevant people and places. The interaction process involves:

- Preliminary questions about a positive upcoming event.
- Recommending a song linked to this event.
- Receiving feedback and making further song recommendations.

The robot begins by prompting the PwD about any exciting future events. If the event is not in the loaded schedule, the robot asks follow-up questions about associated people and places and records them. If the PwD cannot recall a specific event, the robot selects the future event with the highest Importance Score for the next step.

During the recommendation step, the robot uses stored memories to fetch songs linked to positive memories involving relevant people and places. Songs are ranked by mood similarity to the chosen future event (along valence and arousal), and the selected song is played for the PwD.

For system and user critiquing, the robot asks the PwD if the current song helps them remember the event, if they have another song in mind to represent the event, or if they want to be reminded of a different event. If the PwD wants to be reminded of another event, the preliminary questions are asked again, and a song linked to that event is played. If the PwD prefers another song for the current event and knows which song should be played, the robot plays it. If the PwD prefers another song for the current event but doesn't know which song should be played, the PwD (user critiquing) or robot (system critiquing) suggests critiques based on:

- The mood of the song (based on valence and arousal).

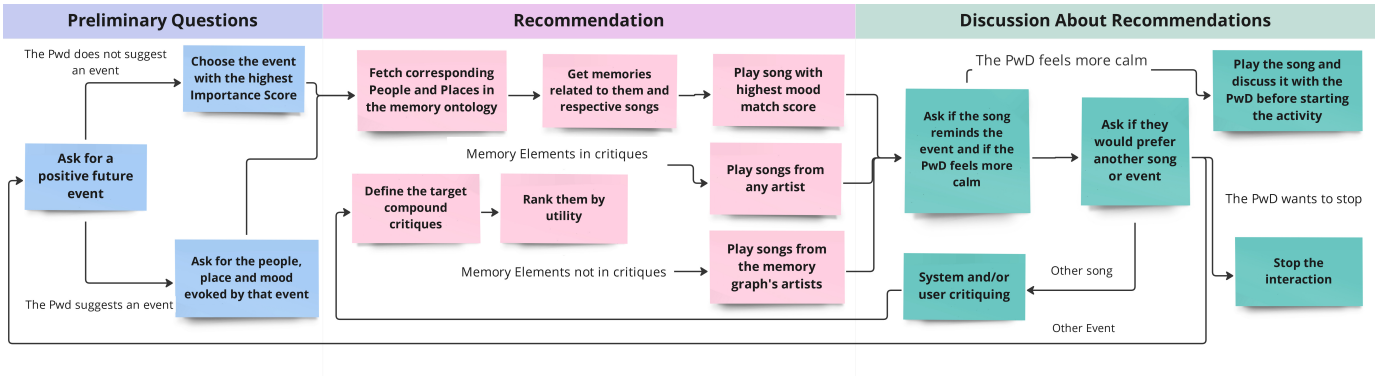

Fig. 3. Framework for the Recommendation Module

- The artist or genre.
- The episodic memory elements (people and places).

The system then proposes a new song using the method introduced by Jin et al. [21], converting the critique into a pattern vector, comparing it to common compound critiques, and calculating their utility using multi-attribute utility theory. If memory elements appear in the critique, the robot chooses a song by the artist linked to that person or place or an already existing song in the memory ontology; otherwise, the critiques can be applied to choose a song without any other restrictions.

The recommendation framework is summarized in Figure 3.

D. Task Assistance Module

The task for this module is designed to be adaptable to a variety of activities, allowing the recommendation system to be customized for different tasks. The main change in our approach to robot-assisted activities is the inclusion of personalized encouragements for PwDs whenever they feel lost or stressed. These encouragements remind the individual not only of the current activity but also of a future positive event previously mentioned. This dual reminder serves to both calm and motivate the PwD, enhancing their overall engagement and emotional well-being during the interaction.

V. Implementation and Evaluation

The implementation is currently in progress on the Navel robot platform. The scheduling module is managed using Radicale [24], the memory module employs Neo4j [33] as a graph database, and the discussion module utilizes RASA [6]. The specific activity to test this implementation has yet to be determined.

Two primary variables will be measured: perceived stress and engagement during the activity. Task engagement, here defined as the percentage of time spent talking to the robot or oriented to the task [25], will be assessed through visual focus of attention on the robot or objects related to the activity, manipulation of these objects, and moments of dialogue with the robot [29]. Emotions will be measured in real-time using facial expression analysis [45], and stress will be self assessed through a visual analogue scale [27]. These measures will be compared across three conditions:

- The robot recommends the PwD's favorite songs.
- The robot recommends songs that trigger MEAMs.
- A control condition where the robot plays a random song.

All songs will be played before starting the activity. In both experimental conditions where the robot recommends songs, PwDs can provide feedback and receive alternative recommendations based on their preferences. Additionally, the system's perceived usability will be evaluated by both caregivers and PwDs.

VI. Future Work

As a next step, a pilot study will be conducted to refine and modify the design and test the validity of our claims.

Currently, all three elements of the Importance Score are weighted equally. A possible improvement over this framework would be to add a learning layer to personalize the weights and allow them to evolve over time.

VII. Conclusion

In this paper, we propose an architecture for using Music Evoked Autobiographical Memories to support Activities of Daily Living for People with Dementia. The system still needs to be tested in a real-life experiment to validate the presented design.

VIII. Ethical Considerations

The user study that will follow this work will comply with GDPR regulations regarding data management for vulnerable populations. The present work has been reviewed and developed with this issue in mind. All of the collected data will be processed locally. The robot responds to stop commands and has an on/off button that can be pressed anytime by both PwD and caregivers.

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