Enhancing Older Adults' Prospective Memory and Experience with Personalized Reminders: Design of the MemFlow Robot Framework

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***Abstract*—As the global population ages, cognitive decline poses significant challenges to independent living for older adults. This paper presents the design and preliminary findings of an intelligent reminder system aimed at enhancing prospective memory (PM) and recipients' experience. The proposed generic system structure aims to address the limitations of current reminder technologies. Traditional reminder systems often struggle to balance providing effective assistance with maintaining a positive user experience. By leveraging robotic capabilities for natural and context-aware interactions, the design aims to deliver effective and personalized reminders (i.e., just as far as needed). Preliminary scenario-based investigations indicate that robotic reminders can potentially lead to better PM performance and user experience outcomes. The study outlines future research directions, focusing on the effectiveness of implicit versus explicit reminder strategies and the overall user experience of the proposed system.**

I. Introduction

The population is ageing, and people are experiencing longer lifespans. As per the United Nations [4], there were 727 million individuals aged 65 and above in 2020. The importance of elderly care is widely acknowledged, informed by these data [19, 33]. Cognitive decline is a common issue among the elderly [1]. Forgetfulness, especially related to prospective memory (PM) tasks, can significantly impact daily functioning. PM tasks involve remembering to perform actions in the future, such as taking medication, attending appointments, or paying bills [37]. These tasks are essential for maintaining independence and well-being. The consequences of PM failures can be quite serious. Missed medication doses, forgotten appointments, or neglected household tasks can lead to health complications, safety risks, and decreased overall quality of life. Therefore, addressing PM challenges is crucial for supporting independent living among the elderly [37, 34, 22].

Many elderly individuals express a strong desire to continue living in their own homes rather than moving to assisted living facilities [25]. This preference for independence is understandable, but it also presents challenges. Fortunately, technology plays a crucial role in supporting elderly individuals who choose to live alone. From smart home devices to wearable health monitors [16, 30], technology can enhance their quality of life. To support elderly individuals in maintaining independent living, researchers and designers have investigated the development of various reminder systems. These systems can be particularly beneficial for older adults, as they help manage daily tasks, medication schedules, and appointments, thus reducing the risk of forgetfulness and enhancing overall safety. By providing timely prompts and alerts, reminder systems empower elderly individuals to maintain their routines and stay organized, fostering a sense of autonomy and confidence. Notable examples include Autominder [34], an activity-based reminder system; CybreMinder [17], a sophisticated context-aware reminder system; mHealth [3], a mobile reminder system tailored for the elderly; and Memory Glasses [32], a wearable, proactive, context-aware memory aid. These systems are designed to prompt individuals to complete prospective memory tasks at the appropriate times, thereby supporting their independence and quality of life.

When designing an intelligent reminder system, it is crucial to balance reminder PM performance with the overall user experience. Users face diverse situations that require personalized reminder strategies, and different prospective memory tasks have varying probabilities of being remembered based on factors like importance, timeframe, and trigger notability. A key consideration is users' limited attention resources. Excessive reminders, while aiming to increase task completion, can overwhelm users and compete for their attention. This can disrupt daily task flow and reduce well-being [7, 8], leading to frustration and potential rejection of the system. On the other hand, research indicates that note-taking, as a form of reminder, influences memory and suggests that excessive reliance on such aids can impair memory performance [18]. Consequently, we deduce that reminder support may reinforce the decline of the individual's PM task performance over time as the individual's PM becomes less challenged and activated (like skill degradation due to automation [31]). This deterioration could negatively affect memory self-efficacy [24, 11]. Therefore, two essential aspects of user experience to consider are memory self-efficacy and flow.

Memory self-efficacy (MSE) is the confidence in one's ability to use memory effectively [10]. Older individuals often exhibit lower MSE compared to younger people [35, 26], which can significantly affect their lives. As memory challenges increase with age, maintaining a positive perception of one's memory becomes vital. A decline in MSE can lead to frustration, anxiety, and a reduced quality of life [9]. Older adults with low MSE may avoid mentally stimulating activities, social interactions, or simple tasks due to fear of forgetting or making mistakes [10, 5]. Therefore, supporting MSE is crucial in designing reminder systems, especially for older users.

Flow, defined as "the holistic sensation that people feel when they act with total involvement," [15] is another critical factor. Csikszentmihalyi et al. [14] proposed that flow can occur in various activities and is associated with happiness and a sense of purpose, counteracting inertia and depression [21]. Research by Hirao et al. [20] shows that experiencing flow in daily life positively impacts mental health. Collins et al. [13] found that among older adults, high-quality flow experiences correlate with positive emotions, lower negative emotions, and increased life satisfaction. Hence, maintaining flow experiences is essential, especially for the elderly, in the context of reminder systems.

The following diagram illustrates the relationship between key factors in designing the generic structure of the intelligent reminder systems (See Figure 1):

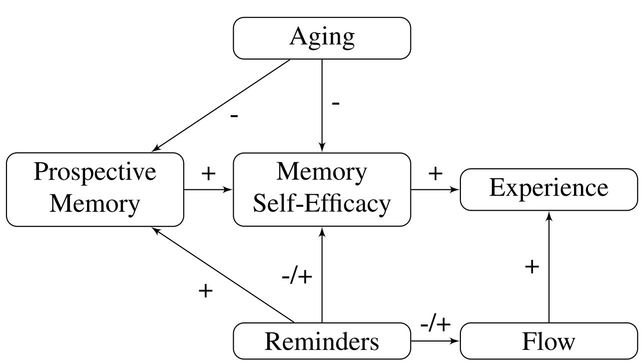

Fig. 1. The Key Factors in Designing The Generic Structure

Despite the importance of these factors, current research has focused primarily on task-completion reminder systems [23, 3], with little attention to prospective memory performance and user experience, specifically memory self-efficacy and flow. Investigating innovative approaches that consider prospective memory performance and its impact on memory self-efficacy and flow is essential for enhancing the independent living experiences of our ageing population.

A critical research question arises: How should an intelligent reminder system be designed to effectively remind individuals while simultaneously enhancing their experience? This question is pivotal in guiding the development of reminder systems that support independent living and cognitive health, especially for older adults. In our study, we propose a generic architecture, MemFlow, for intelligent reminder systems. This architecture aims to enhance prospective memory performance while concurrently improving the user experience for elderly individuals, focusing on memory self-efficacy and flow.

II. Related Work

A. *Prospective Memory*

Prospective memory (PM) is the ability to remember to carry out an intended action at some point in the future [37]. It is an essential cognitive function that allows individuals to plan and execute tasks that are not immediately relevant but will be important in the future.

Prospective memory is particularly important for older adults because it can help them maintain their independence and quality of life [39]. Prospective memory failures are a common type of memory complaint for older adults [36] which can have an impact on their reputation and self-esteem [12] because someone who consistently remembers things is seen as reliable and well-organized, whereas someone who forgets things occasionally is seen as unreliable and disorganized [12]. Thus some individuals rely on external memory aids such as notebooks, diaries and calendars to supplement their memory capacity [29]. The use of digital technology such as smartphones in memory aids designed for individuals is also on the rise [38]. However, this kind of new technology can be challenging for older adults. An important issue with memory aids is that they can only assist users with prospective memory tasks in a conformist manner, which means that unnecessary reminders may occur due to the lack of situated interaction. This limitation may compromise the PM performance of the reminders and negatively impact user experience. Addressing this gap is the objective of our research.

B. *Memory Self-efficacy*

As mentioned in the introduction, memory self-efficacy (MSE) is a concept derived from Bandura's self-efficacy theory, specifically adapted to the domain of memory. It refers to the individual's beliefs about their memory abilities, influencing how they approach and engage with memory-related tasks [6, 27]. Bandura's theory hypothesized that self-efficacy is shaped by various factors, including internal elements like cognitive and biological processes, external elements such as environmental influences and societal beliefs, and the individual's past performances on similar tasks [5]. Similarly, MSE can be influenced and modified by these factors, particularly through experiences and interventions. Research indicates that MSE is dynamic and can fluctuate based on positive or negative experiences. Positive interventions, such as learning new memory strategies, can enhance MSE, whereas negative experiences, like forgetting to perform a task, can diminish it [24, 11]. This variability underscores the importance of targeted interventions to bolster memory confidence, especially as individuals age.

Age-related decline in MSE is a well-documented phenomenon. As people grow older, they often perceive their memory abilities as deteriorating, partly due to actual declines in memory performance. This perceived decline can lead to a self-fulfilling prophecy where individuals exert less effort in memory tasks because they doubt their capabilities [5]. Consequently, a low level of MSE can result in reduced effort and motivation in daily activities, underestimation of one's abilities, and experiencing heightened anxiety [27]. The level of MSE in elderly individuals is particularly crucial for their overall well-being. Enhanced MSE can contribute to better mental health, increased engagement in cognitive activities, and improved quality of life [28]. Despite its importance, the impact of external influencers, such as reminder systems, on MSE has been the subject of limited research. This gap in the literature presents a significant opportunity for further investigation to determine how such systems can be optimized to support memory self-efficacy, particularly among older adults, is crucial for developing interventions aimed at improving their cognitive and emotional well-being.

III. The MemFlow Framework

The MemFlow framework is designed to enhance the performance and user experience of intelligent reminder systems by addressing two primary design goals: maximizing memory performance and improving user experience in terms of MSE and flow.

The framework is structured into two levels of description. The first level identifies a series of capabilities that intelligent reminder systems should possess to meet the design goals. The second level facilitates the identification of relevant system components to achieve these capabilities.

A. Level1: Capabilities

To achieve the design goals, the intelligent reminder systems should possess the following capabilities (See Table I):

Capabilities	Reason
Provide Implicit/Explicit Reminders	Implicit reminders subtly prompt users without interrupting their tasks, while explicit reminders ensure crucial tasks are not forgotten
Be Context-Sensitive	Context-sensitive reminders ensure relevance and reduce disruptions, thereby supporting better task flow and user satisfaction.
Have Memory Personalization	Personalized reminders cater to individual needs, enhancing memory self-efficacy and the overall user experience.

TABLE I
CAPABILITIES

B. Level2: Implementation Forms

To achieve the desired capabilities, we propose a generic architecture for the intelligent reminder system, comprising five key modules: the sensor module, the storage module, the inference module, the decision module, and the execution module (See Table II).

Module	Function	Components	Purpose
Sensor	This module includes various sensors that detect the context of PM tasks.	Cameras, microphones, radar, etc.	To gather contextual information essential for providing relevant and timely reminders.
Storage	This module stores PM tasks and related information.	Databases and user interfaces for reading and writing data.	To maintain an accessible repository of tasks and user data.
Inference	This module reasons about the importance of tasks and the likelihood of remembering to complete them.	Machine learning algorithms and predictive models.	To assess task priority and predict memory performance, enabling more effective reminders.
Decision	This module determines the representation and timing of the reminders.	Decision-making algorithms and scheduling tools.	To optimize when and how reminders are delivered, ensuring they are helpful without being intrusive.
Execution	This module executes the reminders generated by the other modules.	Notification systems and user interface elements.	To deliver reminders to the user in the most effective manner, based on the context and user preferences.

TABLE II
IMPLEMENTATION FORMS

IV. Preliminary findings and future work

Our research employs a scenario-based approach to develop technology that enhances the prospective memory of older adults. By examining various scenarios, we aim to understand how these technologies can improve PM and enhance user experience. Our findings indicate that the usability of reminders is influenced by several factors, including the timing of the reminder attempt, whether the reminders are implicit or explicit, the modality of the reminder, the level of detail provided, and the awareness of the context. We explored the design space of reminder behaviours and discovered that a robot can be highly effective in this context. For example, incorporating a robot into the reminder system can enhance both the execution and sensor modules. Unlike traditional systems, robots can provide implicit reminders through body gestures or eye signals, leading to more natural interactions with users and their environment. Additionally, a robot situated with the user can sense what the user sees, hears, and possibly smells, thereby improving the PM performance and contextual relevance of reminders.

Based on this finding, we employed a body-storming exercise [2] with an elderly living scenario. In this scenario, a user requires assistance to remember his weekly phone call to his son on Sunday afternoons. We assumed that the user, Mike, wanted to call his son this Sunday between 3 and 4 PM to remind him to bring a book and share some news. However, Mike often forgets, so he relies on a robot for assistance. We explored different circumstances within this scenario based on our MemFlow reminder system concept, such as the amount of information included in the reminder, the system's response if Mike is asleep, and whether the robot should remind Mike about the book during the phone call. The results show that robots can be an effective solution for this PM case.

We encounter several research and development challenges, including defining the characteristics of an effective reminder system, integrating this architecture with robotic platforms, and developing algorithms. As a first step, we plan to design and prototype a reminder system based on our current design structure. This initial phase will involve piloting the system to evaluate its functionality and user response. Subsequently, we intend to investigate the differential impacts of implicit and explicit reminder behaviours on prospective memory, flow and memory self-efficacy. In the long term, we intend to compare the user experience of our robotic PM-support system with traditional reminder-support systems. Additionally, we may explore other reminder behaviours and their effects on PM and user experience, thereby expanding our understanding and improving the design of intelligent reminder systems.

V. Summary and Conclusions

In this paper, we have presented the MemFlow framework, designed to enhance intelligent reminder systems by focusing on two primary goals: maximizing memory performance and improving user experience through enhanced memory self-efficacy and flow. Our research emphasizes the importance of personalized, context-sensitive, and implicitly/explicitly delivered reminders to achieve these goals.

Our preliminary findings indicate that robots may improve the user experience of reminder systems. Robots can deliver reminders in a more natural and contextual manner, using body gestures and environmental awareness, which traditional systems lack. Additionally, we discussed the potential benefits of incorporating robots in various reminder scenarios, demonstrating their ability to enhance both prospective memory and user experience.

We acknowledge several research and development challenges ahead, such as refining the characteristics of an effective reminder system, integrating it with robotic platforms, and developing robust algorithms for inference and decision-making. Future work includes designing and prototyping a reminder system based on our current framework, evaluating its functionality, and comparing its effects on PM performance and user experience with traditional systems.

Our long-term goal is to expand the understanding of reminder behaviours and their impacts on PM and user experience, ultimately contributing to the design of intelligent reminder systems that support the cognitive and emotional well-being of older adults.

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