A Comparative Study of Robotic Approaches for Locating Misplaced Objects

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***Abstract*—Misplacing objects is a common problem among older adults with mild cognitive impairment (MCI) that can lead to potential conflicts between them and their care partners. This project aimed to address this issue by proposing two frameworks for a robotic system to help locate misplaced objects. The first approach, a graphical user interface (GUI), allows users to search for objects manually, while the second approach, called "Lost & Found," proactively collects misplaced objects in a bin and informs the user of their location. The project consisted of two parts: a Think Tank session to evaluate the proposed frameworks and a speculative video study to assess user experience and perception of usefulness and ease of use. The results showed that participants frequently misplaced objects on flat surfaces, were comfortable with in-home surveillance for data collection, and preferred the Lost & Found approach for its autonomy and ease of use. Limitations included a small sample size and a lack of in-person studies with older adults living with MCI. Overall, the project demonstrated the potential of innovative robotic solutions to empower older adults, improve their autonomy, and enhance their quality of life.**

***Index Terms*—Robotics, Mild Cognitive Impairment, Object Misplacement, User Study**

I. Introduction

MCI is a prevalent condition among elderly individuals, which results in a decrease in cognitive skills like memory and reasoning. While it is noticeable, the decline is not substantial enough to impact daily activities. Research studies based on the population suggest that the occurrence of MCI in people aged over 65 years ranges from 3% to 19%. As the worldwide population ages, the number of individuals affected by MCI is expected to increase [1] [2].

Misplacing everyday objects is a prevalent struggle among this population. Typically, patients report that they cannot remember where they set down an item. However, in the later stages of the disease, misplacing objects may be evident by unusual placement. Furthermore, glasses, house keys, mobile phones, and wallets are the most frequently lost items [3] [4] [5].

Misplacing objects can cause individuals with cognitive impairment to experience anxiety and frustration. Moreover, caregivers are also impacted as they may be wrongly accused of stealing the lost item, which can create conflicts between the elderly person and their caregivers [6].

Implementing a lost-object-finding system can significantly ease the burden on caregivers, mitigate conflicts between caregivers and patients, and promote independence among patients with cognitive impairment.

II. Related Work

Various technologies have been developed to locate misplaced objects indoors, including Bluetooth low-energy-powered smart trackers such as Tile, Chipolo, and Apple's AirTag. These trackers can be attached to personal belongings and tracked using a mobile app or a home assistant like Amazon's Echo. Radio-frequency identification (RFID) technology is another option that employs small tags to locate items. Numerous RFID-based approaches have been proposed, including a PR2 robot utilizing UHF RFID to identify and locate objects in human environments, commercial systems like Loc8tor providing audio and visual guidance for object location, and a Movinglight system for locating books on bookshelves [7] [8] [9].

M. Patel and S. Chernova [10] introduced a generative graph neural network for proactive robot assistance that anticipates and adapts to users' needs by learning spatio-temporal predictive models of object dynamics. Proactive approaches like this one have the potential to significantly aid older adults in finding misplaced objects within their homes. In this work, we aim to evaluate the perceived usefulness, ease of use, and preferences of older adults living with MCI regarding two different proactive robotic approaches for locating misplaced objects in household environments.

III. Approach

In this study, we compare two approaches designed to assist older adults in finding misplaced objects within household environments. Both approaches employ distinct strategies to address this issue and are developed in the robot platform Stretch from Hello Robot. The research questions we aim to answer in this study are the following:

- Which approach for dealing with misplaced objects do older adults find more useful or have a better experience with?
- How do different levels of autonomy in the robot's decision-making process affect user satisfaction and perceived usefulness?

A. Designed Robot Approaches

Graphic User Interface (GUI) Approach: The Stretch robot navigates through a single-level house, capturing photos of the surroundings. These photos are then processed through an object classification framework, such as YOLO, to identify objects within the images. The robot stores these labeled pictures in its memory. When a person cannot recall the location of a personal object, they can ask the robot for assistance. The robot will display photos containing items that match the provided description on its screen, using a GUI. The user can then view images featuring objects belonging to the lost object class. This method's advantage lies in the robot's focus on identifying object types rather than specific attributes. For example, a household may have multiple phones, but the person may be searching for a specific one. The person can assist the robot in identifying the correct phone by reviewing the captured photos. Once the object is selected, the robot can guide the person to the location where the image was taken.

Lost & Found Approach: The Stretch robot navigates through a household environment, searching for misplaced personal belongings, such as wallets or phones. While navigating, the robot uses its camera to inspect areas of interest and locate commonly misplaced objects. If an object is found, the robot retrieves it and places it in a designated "lost and found" bin. This process allows users to check the lost and found bin when they cannot find an object, increasing the likelihood of locating it. This approach can reduce search time and the stress associated with losing items. Additionally, the robot can gather data and determine when a user is using an object to prevent mistakenly relocating it to the bin. The robot can also notify the user when a misplaced object has been moved to the lost and found bin, encouraging them to store it in a known location. It is important to note that the robot is aware of the intended locations for commonly misplaced objects, ensuring that it will not move an item to the lost and found bin if found in the correct place.

B. Study Design

To evaluate the proposed approached we attended a Think Tank which is a 45-minute session where researchers showcase their projects to older adults living with MCI and their care partners. We had 19 attendees in our session, and we presented them speculative videos of both approaches to encourage a group discussion about their opinions and struggles with misplacing objects. In addition, we conducted a study presenting speculative videos to 10 individual participants. The videos explain the two approaches for locating misplaced objects. We administered a pre-study questionnaire to collect demographic information from the participants, assess their prior experience with robots, and determine the frequency with which they misplace objects. After watching both videos, participants completed a post-study questionnaire to evaluate their perceived usefulness, perceived ease of use, overall experience, and robot autonomy preferences with each approach. The total duration of the study was around 15 to 20 minutes per participant, and it was conducted online via video calls.

C. Hypothesis

We present our hypotheses for the potential results of the Think Tank session and the speculative video study:

1) Study participants are expected to perceive the Lost & Found approach as more useful and easier to use compared to the GUI approach, due to its higher level of autonomy and reduced need for user intervention during the search process.
2) Think Tank participants are unlikely to misplace objects in out-of-sight locations, such as cabinets or drawers.
3) Data privacy concerns are anticipated among Think Tank participants, given that the robot will capture images of their homes during its operation.

IV. Results

A. Think Tank Session

Fig. 1 summarizes the responses of the survey we conducted during the Think Tank session to evaluate the participant's opinions about the GUI approach.

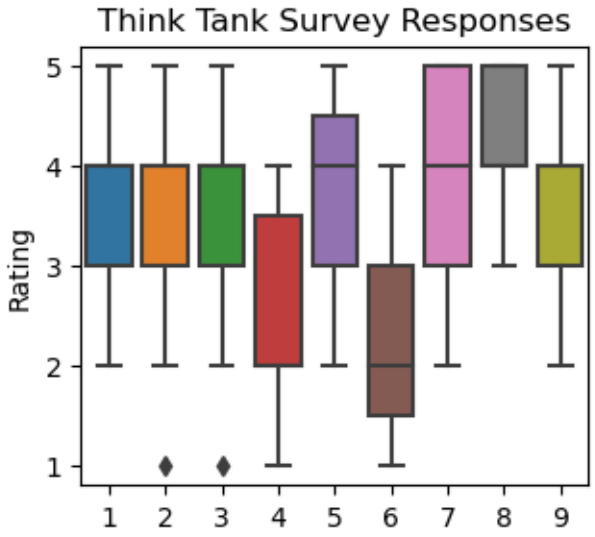

Fig. 1. 1. Frequently require help from my care partner to find misplaced objects, 2. I typically find my misplaced objects in a similar location as where I found it last, 3. I usually find my misplaced objects on flat surfaces, 4. I usually find my misplaced objects in cabinets/drawers, 5. I am comfortable with a robot surveying my home, 6. I think such a robot will undermine my autonomy, 7. I like the current layout of the graphical user interface (GUI) shown in this presentation, 8. I would like the robot to be more interactive, 9. I think this robotic application adequately meets the need described in this presentation.

In addition to the survey, we collected qualitative feedback from the participants. We learned that participants commonly misplaced objects such as keys, phones, tablets, and purses. They often became distracted while holding the object, placed it somewhere, and then forgot where they put it down. Therefore, there is a high variability in the time interval of misplacing the object and being aware that is lost. According to the participants this time interval depends on the object. For example, since they are constantly using their phone this time

interval tends to be short in comparison to other objects such as a purse.

Concerns were raised about the suitability of the solution for multi-story homes and the possibility of objects becoming hidden in the middle of the data collection interval. Some participants expressed a preference for being informed of the object's location rather than having the robot guide them or find it for them, suggesting an interface like Apple's Find My AirTags. On the other hand, a few participants expressed that it would be great if the robot could fetch the misplaced object for you since a lot of older adults have mobility impairments as well. The cost of the technology was also a concern, with participants finding the $20,000 price tag excessive.

Suggestions for improvements included incorporating Bluetooth, RFID, or Apple Air Tags technology to locate out-of-sight objects, making the interaction more akin to Amazon's Alexa, and designing the system to perform additional tasks beyond locating misplaced objects.

B. Speculative Video Study

Tables I and II show the data collected in the pre-study survey containing the participant's demographics, prior experience with robots, and an insight in their misplacing behavior.

TABLE I
PRE-STUDY SURVEY RESULTS (PART 1)

ID	Age	Gender	Device Use
01	24	Female	Daily
02	25	Male	Daily
03	25	Male	Daily
04	24	Male	Daily
05	25	Male	Daily
06	25	Female	Daily
07	24	Male	Daily
08	25	Male	Daily
09	25	Male	Daily
10	23	Male	Daily

TABLE II
PRE-STUDY SURVEY RESULTS (PART 2)

ID	Interacted with Robot	Misplace Frequency	Search Time
01	No	Monthly	15-30 mins
02	No	Daily	5-15 mins
03	No	Weekly	15-30 mins
04	No	Monthly	15-30 mins
05	Yes	Rarely	5-15 mins
06	Yes	Daily	15-30 mins
07	Yes	Weekly	15-30 mins
08	Yes	Weekly	<5 mins
09	Yes	Rarely	5-15 mins
10	Yes	Daily	<5 mins

The study participants have an average age of 24.5 years, only 20% are female, they use technology in a daily basis and 60% of them have interacted with a robot before. Furthermore, 60% of the participants misplace objects either daily or weekly and 50% spent between 15 and 30 minutes searching for them. Finally, only one participant lives with someone who has been diagnosed with MCI.

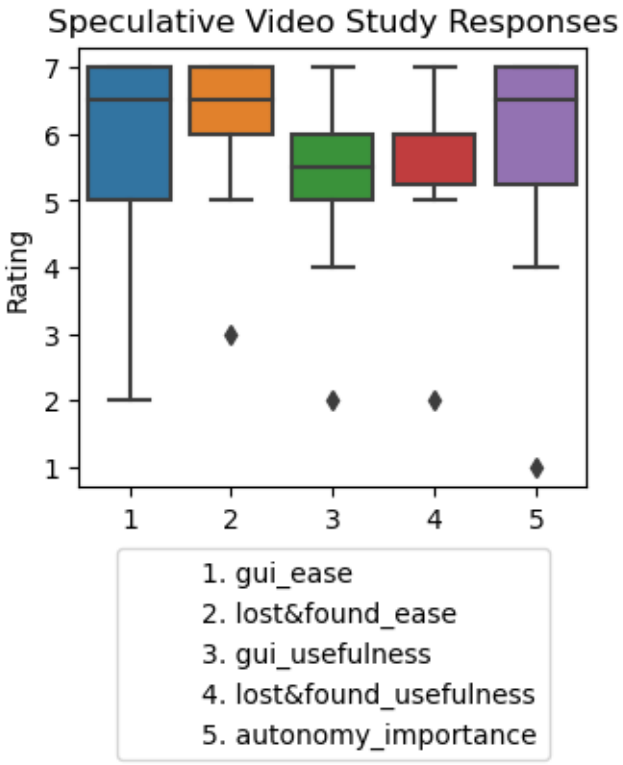

Fig. 2. Post-study Responses

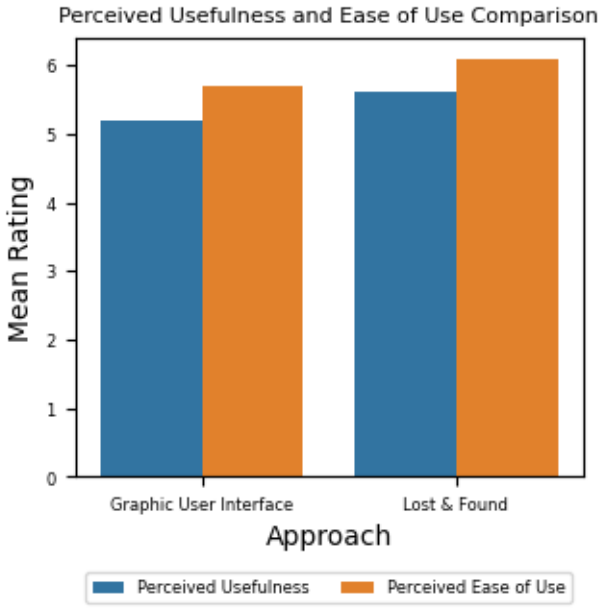

Fig. 3. Participant's Perceived Usefulness and Ease of Use

From the post-study survey, we obtained information about the perceived usefulness, perceived ease of use and level of robot autonomy preference for each participant (see Fig. 2 and Fig. 3). Furthermore, Table III summarizes the participant's preferences related to expected experience and level of robot autonomy.

TABLE III
USER PREFERENCES FOR DIFFERENT APPROACHES

Metric	Approach	% of Preference
Expected Experience	Graphic User Interface	30%
	Lost & Found	70%
Autonomy Level	Graphic User Interface	40%
	Lost & Found	70%

The participants also expressed that the autonomy level in the robot is highly important in this application since we obtained an average rating of 5.7 from the post-study survey. Moreover, to evaluate the validity of the Likert prompts for perceived usefulness and perceived ease of use, we calculated the Cronbach's Alpha value. The resulting value, which exceeded 0.7, indicates that the responses exhibit a strong internal consistency (Table IV).

TABLE IV
CRONBACH'S ALPHA COEFFICIENTS

Metric	Cronbach's Alpha
Perceived Usefulness	0.831
Perceived Ease of Use	0.915

Finally, we also obtained qualitative feedback from the participants which is summarized below:

"Which approach do you prefer for dealing with misplaced objects, and why?": Most participants preferred the Lost & Found approach, citing reasons such as reduced search time, convenience, and not needing to move around. Some participants favored the GUI approach, stating that it allowed them to search for specific items and could be more useful for those who do not frequently leave items on the floor.

"How do you think different levels of autonomy in the robot's decision-making process might affect your satisfaction and perceived usefulness of each approach based on the videos?": Participants expressed varying opinions regarding the importance of autonomy in the decision-making process. Some believed that increased autonomy would lead to greater satisfaction and usefulness, while others preferred more interaction with the robot. Concerns were raised about the robot's ability to memorize routines and adapt to the needs of older adults.

"Based on the videos, do you have any concerns or suggestions for improvements for either approach?": Participants suggested improvements and raised concerns for both approaches. For the GUI approach, suggestions included highlighting the object's location in the images and faster robot movement. For the Lost & Found approach, concerns were mentioned about the robot's ability to identify the desired object, reliability, and potential damage to objects. Combining the two approaches and enhancing robot movement capabilities were also recommended.

V. DISCUSSION

The Think Tank session revealed that older adults frequently struggle with misplacing objects, often requiring assistance from their care partners to locate them. This can lead to potential conflicts between older adults and care partners, making it crucial to provide tools that empower older adults and minimize their reliance on others. Furthermore, our findings indicate that objects are often misplaced on flat surfaces, rather than out-of-sight locations like cabinets or drawers, supporting hypothesis 2. This suggests that the current approaches could be successful in finding objects since they are not typically hidden or occluded.

Contrary to hypothesis 3, Think Tank participants were comfortable with the robot's in-home surveillance for data collection. This could be attributed to their familiarity with new technologies and healthcare advancements, as they frequently participate in Think Tank sessions. However, it may also be due to a lack of awareness regarding data collection practices and potential misuse of personal information. It is therefore essential to be transparent and clear with users about how their data is being handled. Importantly, participants did not feel that the robot would compromise their autonomy, as it would reduce their reliance on care partners when searching for objects. They also expressed a desire for a more interactive robot, emphasizing the need for improved speech capabilities and more natural user interactions in future systems.

The speculative video study showed that participants tend to misplace objects at least once a week and spend considerable time searching for them, indicating that the proposed frameworks could help reduce search time. As shown in Figure X, participants found both approaches useful and easy to use, with the Lost & Found approach receiving slightly higher ratings for perceived usefulness and ease of use. This does not entirely support hypothesis 1. However, the main factors differentiating the two approaches from the participants' perspective were the level of autonomy and the anticipated user experience. Most participants believed that the Lost & Found approach better met their needs in terms of autonomy and had higher expectations for a more positive experience with this framework. The Lost & Found approach, being a proactive system where the robot ensures misplaced objects are placed in the bin, was perceived as requiring less effort from users when trying to locate lost items.

Overall, this project has shed light on the challenges faced by older adults with mild cognitive impairment in locating misplaced objects and has demonstrated the potential for innovative robotic solutions to address these issues. While there is room for improvement and further research, the results provide a solid foundation for the development of practical and user-friendly tools that can empower older adults, enhance their autonomy, and improve their overall quality of life.

VI. Limitations

Several limitations were present in this study, which should be taken into consideration when interpreting the results. Firstly, the speculative videos used in the study only depicted the robot performing its tasks flawlessly, without any failures. This may have positively influenced participants' perceptions of the approaches and could potentially lead to an overestimation of their usefulness and ease of use.

Secondly, the use of speculative videos alone is insufficient for accurately assessing participants' experiences with both approaches. Conducting an in-person study would provide more comprehensive and reliable information regarding user experience and the effectiveness of each approach in real-world situations. Another limitation was the demographics of the participants in the speculative video study. The study primarily included young adults, who may not accurately represent the older adult population living with MCI. Additionally, only 20% of the participants were female, indicating a need for a more balanced sample to better reflect the target user group.

The sample size in the speculative video study was also relatively small, which may limit the generalization of the findings. A larger sample would provide more robust information and help to draw more reliable conclusions about the effectiveness and user experience of both approaches.

Finally, conducting one-on-one studies with older adults would be beneficial for gathering more in-depth information and insights about their experiences and preferences, which would further inform the development and refinement of the proposed robotic solutions.

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