Feasibility study of a robotic medication assistant for the elderly

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Abstract

Management of complex medication regimens by older people poses a significant challenge wherein use of information technology could play a role in improving clinical efficacy and safety of treatment. The use of computing devices, however, presents a special challenge to older people given their physical and cognitive limitations. Robotic platforms show promise for extending the functionality of the user interface to make personalized interaction engaging and empowering, and for proactively reaching out to older users to support their healthcare delivery. We believe that a robot combining a touch screen and voice based interface could offer an effective platform to meet these requirements. This paper reports on a feasibility study of such a system for helping older people with their medications. We exposed 10 relatively independent residents of an aged care facility to our robot running a medication reminding application while they took their medications. The interaction was followed by a questionnaire and structured interview to elicit their opinions and feedback. We found the application to be well received as all users could successfully complete the session, and most subjects found it easy to use, appropriately designed and felt confident using it. A number of technical errors were uncovered, and the results suggest opportunities to refine the equipment and dialog design to provide a better robotic medication assistant.

Keywords: Aged care; Medication safety; Robotic assistance; Touch screen; Voice interaction

1 Introduction

Higher prevalence of chronic and degenerative conditions in older age often requires use of multiple medications on a regular basis. The quality use of medications is important to improve clinical outcomes and overall quality of life. However, older people are often unable to effectively manage the regimen of medication due to a number of reasons including forgetfulness and apathy.

The complexity of medication regimens is another reason often cited for medication non-adherence among older adults. Many strategies have been deployed to improve adherence to medication in the elderly (Banning 2009), but Morris and Schulz (1993) have pointed out that taking medication is not only a pharmacological process but also a psychological, interpersonal and social process as well.

It is increasingly being suggested that patient-centred care may promote more empowerment and autonomy, both generally and with respect to compliance with medication, in particular for old people and nursing home residents (Hughes 2008). However, implementing patient centric models of care would require resources of time and people, both of which tend to be constrained. Therefore, it may be worthwhile exploring technologies that could deliver desired outcomes by meeting usability needs of intended users and restoring their confidence in being self supported.

Despite rapid development of applications to support older people to self manage their health conditions in recent years; the presentation of information and the use of devices needs to be carefully considered for this age group. The limitations posed by declining cognitive capacities, and by increasing sensory and physical disabilities, have important implications for an interface design (Sutter and Müsseler 2007). For example, long sightedness, lens implants, progressive macular degeneration and other visual disturbances limit readability. Changes in motor skills, including slower response times, coordination problems, shaky hands and progressive arthritis leading to stiffness and greater variability in movement (Nic 2009) make it difficult for older people to use current input devices, such as a mouse or keyboard. Hearing difficulties and use of hearing aids that distort sound make it difficult to understand spoken dialogues. Several studies (Czaja and Lee 2002) have also shown that cognitive abilities such as working memory, attention and spatial abilities are important predictors of performance of computer-based tasks. Working memory that enables learning of new tasks or recall of complex processes and attention capacity that enables concurrent activity handling or switching of attention between competing displays of information are often challenged in elderly people. A static desktop computer offers limited opportunities for a timely or regular delivery of information in this context.

Touch screen based interfaces that make the interaction simple, directed and goal oriented, can offer a potential alternative to address some of these challenges (Murata and Iwase 2005). To extend the information presentation capabilities of a touch screen based user interface, we chose a robotic platform. Robots have recently been shown to make interaction with computers interesting, engaging and personalized, and to successfully engage older users (Marcel et al. 2008). Robots also offer a unique opportunity to add an interpersonal element to inform, empower and support older users and also leverage formation of an affective or social relationship (Looije et al. 2010).

In this paper our approach to human-computer interaction on a touch screen computer mounted on a self navigating robot is presented. Before discussing the intervention in section 3, the findings from the literature are discussed in section 2. In section 4 the testing of the user interface is described wherein older adults living in a residential aged care facility used a medication reminding module. This is followed by the discussion and conclusions in sections 5 and 6.

2 Related work

This research was informed by the previous research and insights gained around the use of technology for older people, with reference to healthcare and medication management in particular.

2.1 UI for older people

Appropriateness of input devices and user interfaces for older people has been studied widely. Older people are reported to deal better with gesture based and touch screen systems than with standard keyboard mouse systems (Tobias 1987), (Hollinworth 2009). Familiarity with gestures has been reported to improve usability (Stößel et al.) and touch screen systems have been shown to have better usability for older people (Fisk et al. 2009). In this scenario it could be argued that routine use of ATM machines by older people makes them familiar with touch screen based user interface and this could be leveraged.

Older adults have also been reported to prefer multimedia presentations over simple text display (Ogozalek 1994). Therefore for the given scenario it was thought more appropriate to create a voice, text and image based interactive user interface. More details about which are discussed in section 3.

2.2 Human robot interaction and healthcare

In the past decade, the methodical, scientific study of human-robot interaction has looked at perceptions of various portions of a robot's appearance, personality, and behaviours (Fong et al. 2003). Healthcare robotics is currently an active research field where studies in Human Robot Interaction have been contextualized for nursing home environments and healthcare domains (Pineau et al. 2003). More recently (Looije et al.) have reported persuasive behaviours of a robot tend to promote health self management in older people.

2.3 Dialoguing in healthcare

The appropriate use of automated dialogue systems in healthcare has also been researched widely. The studies on automated dialogues delivered to patients using telephonic support (Migneault et al. 2006) found that personalization and tailoring of dialogues based on principles of behavioural psychology improves acceptance and delivers optimum clinical results. Bickmore and Giorgino. (2006) have identified several characteristics applicable to dialogues in healthcare such as criticality, privacy, continuity, empowerment and initiative, which support patient safety and respect. The structure of the dialogues for this study was designed incorporating the above in addition to special emphasis on motivational support and providing freedom of choice at every step of the reminding process.

2.4 Medication support systems

Typically a nursing home resident routinely consumes an average of 7 scheduled plus 3 as-needed medications; however, more than a fourth of these individuals take 9 or more medications (Ruppar et al. 2008). Not surprisingly poor adherence to prescribed medication is a common problem. Older adults often report forgetting as a common reason for missed doses (Conn et al. 1994). This is true regardless of the presence or absence of cognitive impairment. In order to support this forgetfulness many electronic devices have been developed to prompt and monitor medication administration. In a systematic literature review automated voice activated measures have been shown to have a significant impact on adherence and outcomes (van Eijken et al. 2003) and so does education and social support. In another review (DiMatteo 2004) reports that practical social support offers maximum advantage to improve medication adherence. Use of a social robot to offer reminders and serve as a medication assistant could therefore be very usefully deployed.

Moreover, it has been shown that some forms of remote monitoring for correct medication administration significantly improves medication adherence (Friedman et al. 1996). Therefore it would be appropriate for the robot to inform the family members, caregivers, pharmacists and/or doctors about the medication administration events after seeking permission of the user. Furthermore, informing healthcare professionals about the issues or problems with medication could improve timely correction of errors and safety. Use of inappropriate medication in the elderly is common and often results in adverse events due to physiological changes associated with aging (Fick et al. 2003), therefore safe prescribing should be supported in addition to promoting adherence.

3 Intervention

The robot used for the purpose of testing is shown in Figure 1. The form factor and functionality of this robot was derived from earlier studies by the researchers at University of Auckland (Broadbent et al. 2009).

As seen in Figure 1, the robot consists of a movable head, rotatable torso, and a mobile platform. Two speakers near the touch screen and a video camera on the top of the screen constitute additional input/output devices. Low-level control functions and navigation are handled by a single-board computer running the Linux operating system. Service applications are running on a similar computer under the Microsoft Windows XP operating system. The two computers are connected via an Ethernet connection.

Ultrasonic sensors for obstacle avoidance are located in the mobile platform (the lower part of the robot in

Figure 1). A tray is fixed to the torso in order to carry measuring devices used by some of the service applications. These external devices are connected to the robot via a USB hub.

Figure 1: The Healthbot robot

3.1 Architecture

The robot used for this study is a joint development of the University of Auckland/Auckland UniServices in New Zealand, with ETRI and Yujin Robot Co. Ltd., in South Korea. The architecture of the robot consists of four layers: robot hardware, a robot software framework (RSF), a robot application programming interface (RAPI), and service applications. Robot hardware, RSF and RAPI were developed by Yujin Robot Co. Ltd.

The robot hardware consists of a differential drive mobile platform, two single-board computers, sonar sensors, microphone, speakers, touch-screen mounted on an actuated head, camera, and USB ports. In the past year we have designed, implemented and conducted a field test on the dialog and event management system for the robot that allows it to undertake reconfigurable spoken and text/touch screen dialog with the patient for key healthcare and support tasks (Jayawardena C. et al. 2010). The user interface was customized for the purpose of medication management module trial. In the context of a medication reminder, the robot can provide the patient with reminders to take their dispensed medications and engage in dialog to collect information about any issues that may be inhibiting adherence to the medication plan. The system is based on interoperability with the local pharmacy software patient medication record format and a W3C Simple Object Access Protocol (SOAP) service oriented architecture interfacing the robot to a Web-based electronic medical record over 802.11 wireless communications and employing XML based dialog specifications.

3.2 The user interface

Although each alternative has its tradeoffs, considering the nature of the challenge, we designed the interface using the principles/elements captured in Table 1, discussed further in the remainder of this section.

	UI Characteristics
1	Use of touch screen as an input device
2	Dual output (text and voice)
3	Integration with assistive technology
4	Ethical considerations
5	Network computing
6	Adaptive and adaptable interface
7	Presenting self guidance
8	Automated dialogue system
9	Mixed initiative user interface
10	Logging and reporting functions

Table 1: Healthbot user interface design principles

Use of fingers to flick a switch or to indicate a choice on a menu of buttons is perhaps the simplest and commonest way that humans have been interacting with technology. We preferred use of touch inputs over speech recognition given the current status of Automated Speech Recognition technology which has serious limitations for ambient voice recognition for use in elder care, as summarized in a recent literature review (Young 2010). It is not only frustrating to use but also highly error prone. Therefore, we decided to defer the use of this input option for this study.

The display of text and options simultaneously with spoken dialogue creates reinforcement where gaps in either visual or hearing abilities get supported. The visual display is simplified to present a single piece of information or instruction at a time, thus minimizing the challenge with respect to attention and memory.

The system presents a single task/instruction per screen (driven by Abode Flash programming) written in bold letters against a bright contrast followed by not more than three large clearly labelled soft buttons to improve clarity of choice selection and reduce response time compensating for motor skill limitations (Murata and Iwase 2005). The soft buttons change colours and make a distinct sound confirming haptic input. The audio reproduction of displayed dialogue is enabled (through customized speech generation software) in relatively loud volume (which is adjustable) through the mounted speakers alongside the touch screen.

Integration with assistive technology becomes possible by virtue of mounting the screen on a mobile robotic platform. Although the robot is intended to be able locate and self-navigate to the user in its final design, it was manually driven for this short trial. It would be able to drive itself close to the person (as well as to a self-charging station), carry medications in its tray and take the initiative to start interactive sessions by virtue of mixed-initiative design. In the future, integration with other smart home technologies could also be attempted.

The touch screen computer is wirelessly connected to a remote server that holds relevant personal and clinical information in a secure manner. The information is released only after the confirmation of user identity and appropriateness of schedule (e.g. right information at the right time as indicated by the prescriber). The patient identity that is received from the front end client results in a query to the server database for relevant information.

This information in turn is sent back to the client for customizing the interaction.

Incorporation of an adaptive and adaptable interface allows personalization and customization of the system. User identification is made possible by face recognition, resulting in loading of information relevant to the person in real time. Hence the system can customize display information/dialogues according to the person's given preferences, clock, calendar, pre-programmed schedule (of prescribed medication according to the physician) and can, in real time, read from and write to the remote database (e.g. the electronic health record). The preferences, sequence of activities and schedules can be customized locally or even remotely.

Presenting a self guiding interface that prompts or guides the user for intended actions at the end of each dialogue or screen (e.g. 'please press the "done" button below when you...') attempts to resolve ambiguity. The presented information or task during a session assumes success of completion but builds redundancy for failure (e.g., 'Have you already done...? If not then press...'). The system attempts to correct unintended errors and encourages user to continue interaction ('Oops! There seems to be some problem. Would you like to try... again?'). By clearly mentioning the features and options available to the user up front and guiding in the face of mistakes, we hope to minimize user anxiety about what is expected of him/her at each stage (Marqui A. et al. 2002).

An automated interactive dialogue system was used to enable the abovementioned features (see Figure 2). It was based on branching tree logic encoded in our XML dialog notation), where depending on a particular choice indicated by the user the screens progress along the logically appropriate branch. The automated dialogues around medication management are based on behaviour change theories (Bickmore et al. 2005) and are tailored in real time to each instance of interaction. The user is addressed by preferred name, encouraging them along the lines of motivational counselling to ensure successful and safe use of medication.

Ethical considerations must form an important part of any interventions as intimate as those involved in aged care, and in light of the vulnerability of this population. It is possible to design a technological intervention in the healthcare domain to become intrusive and disempowering to the users by virtue of passive monitoring and delivering instructions expecting compliance (Tiwari et al. 2010). This ethical concern is addressed by careful choice of dialogues that build skills instead of encouraging dependence (e.g., 'Please read the label on your bottle and confirm if it reads...'). The presentation of information empowers use to make a choice at each stage putting him/her in the position of control (e.g., 'Would you like me to inform...'). Healthcare services also demand being sensitive to issues like safety, accuracy, trusts and teamwork; making it essential to keep healthcare providers and caregiver in the loop of information. It could be made possible by offering the users to enable their medication use information to be shared securely online with the healthcare team and/or concerned family members, especially when things go wrong (e.g. choosing wrong medication, running out of supply, refusal to comply, etc).

Resolving the ambiguities around initiation and course of dialogue depends upon user goals and focus of attention. The recording of task completion (or failure of it) requires the use of mixed initiative interface as described by Horvitz (1999). In order to minimize reasoning about whether to act or not to assist a user with an autonomous service, we can also consider the action of asking users about their goals. For example, the user is also able to self-initiate and complete the medication task even without invoking the reminder function, where the dialogue begins by asking "Have you already done....?"

Logging and reporting functions enable recording of the dialogue path taken by the user, list medications taken by date and time and perform video logging of actual intake. These data are stored to a remote server and presented over a web interface to healthcare providers authorized by the user, so that they could observe the events and intervene if necessary. User can also send a text message to a caregiver through the dialogue system

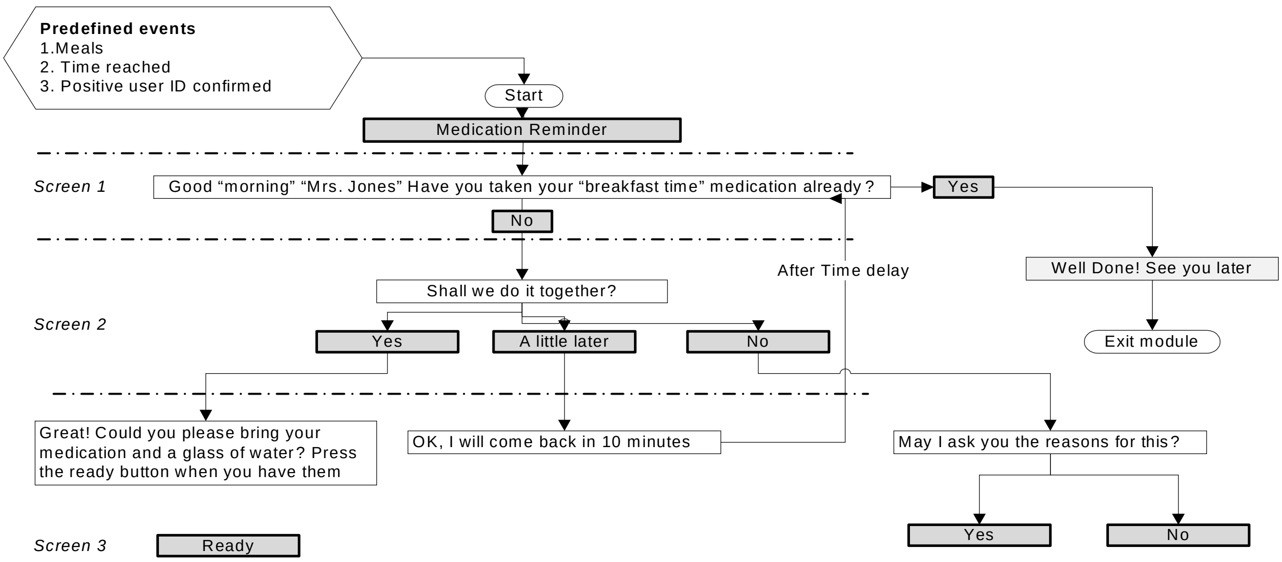

Figure 2 – An example of the branching tree logic

to physically assist in case something is not going right (the system may offer to initiate this, e.g., 'Oh! That is not correct, should I call someone to help you?'). In the future, assistance via tele-presence could also be enabled.

4 Evaluation

The aim of this study was to assess the usability, feasibility and appropriateness of a medication management support system mounted on a robot. We obtained ethics approval from the institutional ethics committee. The trial was conducted in an Aged Care Facility (ACF) in suburban Auckland that houses approximately 400 residents in a range of accommodations and levels of dependence. We sought assistance from their management with random selection of candidates who would be willing to participate in this trial. After circulating a notice we received names of 19 residents who would be interested in participation and, after initial introductions, 10 people expressed willingness to participate.

After sharing the participant information sheets and signing of consent forms we sought approval to collect current prescription data from their pharmacies to populate our database. The export files from pharmacy systems was generated and read by the robot software to incorporate relevant contents into the dialogue.

4.1 Participant profile

As shown in Table 2 below, the 10 participants were distributed across 4 different independent residential blocks in the ACF, and ranged from 69 to 94 years of age with half of them above 80 yrs and mean age 80.5. The evenly distributed five males and five females included two couples.

Patient	Location*	Age in yrs	Gender	Pharmacy**
1	BS	73	Female	i
2	LT	79	Female	iii
3	RM	77	Female	ii
4	RM	80	Male	ii
5	RM	69	Male	ii
6	LT	77	Female	i
7	LT	94	Male	ii
8	BS	87	Male	ii
9	LT	87	Male	ii
10	LT	82	Female	ii

*BS, LT & RM are abbreviated names of 3 multistorey buildings in the ACF complex. ** i, ii and iii are 3 geographically separate pharmacies

Table 2: the Participant profile

The participants had their living quarters spread across various multi-storeyed buildings (abbreviated building names -BS, RM & LT) and received their medications regularly from 3 different pharmacies (i, ii & iii). Respondents organized their medications either in pill boxes or stored as loose bottles (that included strips, lotions, inhalers and creams). Some of them received directly pre-packed sachets (through a robotic dispensing system – not related to the robot assessed in this study) or blister packaged medication where all pills for a particular day and time were packed together for convenience.

Being an exploratory study, it was conceived that a small sample size should give us the insights to guide our further solution development directions and that this was more appropriate than pursuing a larger number of respondents at this stage in the hope of achieving statistically significant measures for hypothesis testing.

All the participants were scheduled to meet with the robotic medication assistant on a convenient morning when the robot shown in Figure 1 would visit them to remind about their medication. The robot was accompanied by a technician and the first author (a trained physician).

The participant profiles might contribute a selection bias because the voluntary expression of interest in participation could draw more interested and capable people. In fact 4 out of 10 participants had already participated in earlier trials conducted under same project.

4.2 Video analysis

The recordings were made of users interacting with the robot as it moved into their living quarters at the scheduled time. The users had agreed not to take their morning medications earlier that day and took them when prompted by the robot.

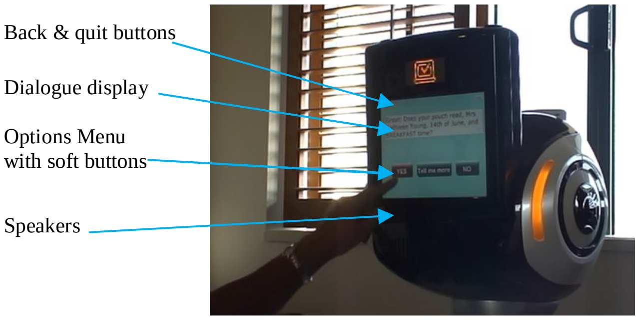

Figure 3 – The session in progress

Figure 3 shows a resident making a selection in response to the robot. As seen in the figure the touch screen has 3 sections. On the top corners of all screens are back and quit buttons. The white text box with black text in the upper two thirds of the screen displays the dialogue that is spoken in large bold fonts. Large clearly marked soft menu button below that offer the menu of choices. The number of choices does not exceed a maximum of three on any given screen. The GUI is kept simple and clear to minimize cognitive load while maintaining ease of use for older people. Text display in large fonts and bright contrast improves readability, while the clearly marked large soft buttons simplify indicating choices.

Participant	Age	Medications organized as	Cognitive status	Computer literacy	Previous participation in robot trial	Errors made by user	System errors	Backtracking	Total time (min.)
1	73	Pouch	Average	None	No	2	3	0	5
2	79	Bottles	Good	Yes	Yes	0	5	0	3.2
3	77	Packaged	Average	None	No	1	3	0	2
4	80	Pill box	Good	Yes	Yes	0	3	0	2.3
5	69	Bottles	Good	Yes	Yes	0	6	0	6
6	77	Bottles	Average	None	No	1	7	1	9.3
7	94	Bottles	Good	Yes	No	1	6	1	4.7
8	87	Pill box	Good	Yes	Yes	0	4	0	2.7
9	87	Bottles	Good	Yes	No	3	7	0	5.5
10	82	Pouch	Good	Yes	No	1	4	1	2.1

Table 3 – Results of video analysis

The results of video analysis are presented in Table 3. To keep the interview time short and not cause significant delay in medication intake, the researcher made subjective observations about their cognitive status and suitability of the robot for these people from a general clinical perspective. Since the issue of medication is sensitive to the patient's safety, the researcher not only explained the process, and supervised and supported the users during the session, but also took noted areas needing improvements, reason/s for getting stuck or backtracking and reason/s for errors.

The results of video analysis showed that although all users were able to complete the interaction successfully irrespective of age or cognitive status, the presence of the researcher and his prompting was an influencing factor in this exploratory study, and we are not sure as to how the sessions would have progressed unsupervised. We took the approach that to learn the most about areas for improvement the researcher would prompt the users through sticking points after noting the nature of the error that caused the problem.

Interestingly, there was no significant relationship observed between occurrences of errors or time taken to complete the session, in relationship to age, computer literacy or previous exposure to the robot. This observation highlights the fact that in this study, mild cognitive impairment and/or unfamiliarity with computers or robots did not impair the medication reminder function's usability.

One relationship that stands out was between the way medications were organized and the errors generated, as well as time taken. Users who had medications loosely arranged in bottles and strips (5 out of 10), unsurprisingly took almost twice as much time than those who had them organized as pouches/blister packaging or used pill boxes (mean task completion time 5.7 minutes vs. 2.8 minutes). The same group was almost twice as likely to encounter errors as those who had their pills organized in pill boxes, sachets or blisters (64.6% of total errors were in the bottles and strips group vs 35.4% errors in others).

The results may not be surprising but the reasons were variable. The main problem was related to our screen design where we had categorized methods of pill organization and user could choose only one option. Most users had their pills organized in multiple ways and were confused as to which option was most appropriate to choose. We had failed to anticipate this as we had been informed that use of the robotically packed sachets was the norm in this ACF. Other sources of errors (across all categories) are shown in Table 4.

Errors made by users		System /design errors	
Typographic errors	6	Confusing options	14
Medication identification errors	1	Voice generation errors	6
Inappropriate choice of option	2	Soft button (touch screen) errors	12
		Pronunciation errors	3
		Inappropriate utterance	3
		Other system errors	10

Table 4: List of errors recorded

Mainly there were problems with face recognition, typographic errors while entering names (the backup to face recognition), inability to handle "null or error" values entered into the system (wrong name, wrong timing, network failure etc.) and some were processing failures including voice generation problems and soft button operation failures.

Most of the system or design errors were perceived by the engineering teams as not too difficult to correct in the next iteration. Some of the errors in the navigation system (ignored in this study) or voice generation problems could require hardware assistance from original equipment manufacturers.

4.3 Questionnaire analysis

Participants were asked to respond on a 5-point Likert scale to the questions shown below in as a part of figure 4. On the Likert scale 1 indicated strong agreement and 5 indicated strong disagreement. Responses were clubbed for the sake of clarity, where 1 & 2 (Strongly Agree and Agree), 4 & 5 (Disagree and Strongly Disagree) and 3 (Neutral) represent three bars in figure 4.

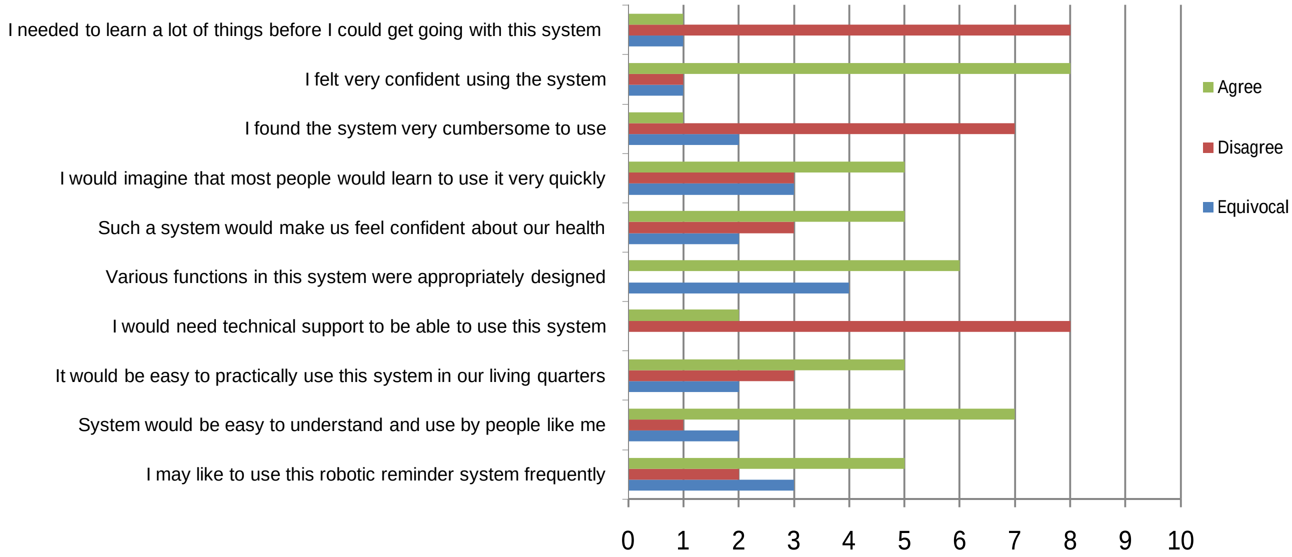

Figure 4 – Questionnaire analysis

X Axis represents number of respondents, Y Axis represents the questions asked

Owing to the small sample size, the results provide no clear association between age, type of medication packaging, pharmacy or residential location and the responses. The responses may hint, however, towards the following two important observations:

Firstly, our assumptions about the appropriateness of the user interface design for the older people were affirmed – the system was well received. Most users found the system easy to use, appropriately designed and felt confident about using it. This is reaffirmed by the observation that most users did not find the system cumbersome, neither did they feel they needed to learn a lot before using the system nor felt that they needed support during its use.

Secondly, the results were mixed with respect to whether the users would like to use the system regularly, regarding the practicality of a robot moving around in their living quarters and whether it would build confidence about their health. They were also not sure if their other peers would learn it easily probably because respondents were aware of the varying degree of cognitive capability in their peers in the facility.

4.4 Structured interview

With a view to explore further the overall impressions of the users and to identify some of the design needs for future developments we conducted a structured interview. The subjective opinions could be coded and inferred as definitive answers. Figure 5 summarises the questions asked and the responses in a single graph.

The data indicate some themes which could be considered important indicators for future design work. The respondents tended to be strongly opinionated towards one way or the other as seen in the data showing minimal "Maybe" responses. There was almost unanimous desire for a smaller static device instead of the large moving robot given the practicality of this in a small living space such as the ACF apartments, as well as relatively good mobility of respondents and obtrusiveness of the robot. However, this could not be generalized to more dependent and physically challenged users who might have a different view. Moreover we are not sure if the same response would be valid for a multifunctional robot as opposed to a single application tested in this study. Most users liked the idea of a robot bringing their medication along as it comes to remind them. The limitation in utility of this idea being fetching the glass of drinking water to swallow the pills, for which users will have to get up anyway. Most respondents strongly wanted some form of side effect surveillance system because many of them have had side effects from their medications where they were unsure what was happening and even the doctors failed to detect them for months. A few patients reported coming across side-effect information somewhere and asking the doctor specifically and only then it was recognized and addressed.

Refill reminding was another big issue, where the users indicated that they would benefit greatly from being reminded in advance. It was reported that many times prescribers take a long time to give appointments and some of them come to the clinic on specific days. If the residents forget the exact day then they may have to wait without medication till next week for the doctor to become available at the ACF clinic. There was almost unanimous desire by the respondents to keep their family members and/or caregivers in the loop about the medication processes. They indicated that this was not only for the sake of keeping family informed but also to ensure that someone is there to respond in case something was going wrong.

On the other hand the users found the idea of being quizzed or being pursued about remembering details of their medications as bothersome and futile exercise. They were also less interested in knowing about other residents who are on the same medication and how they were doing. Unexpectedly, the respondents almost unanimously disliked the idea of changing the mechanical robotic voice to a more familiar human voice (e.g. voice of a family member or of their pharmacist).

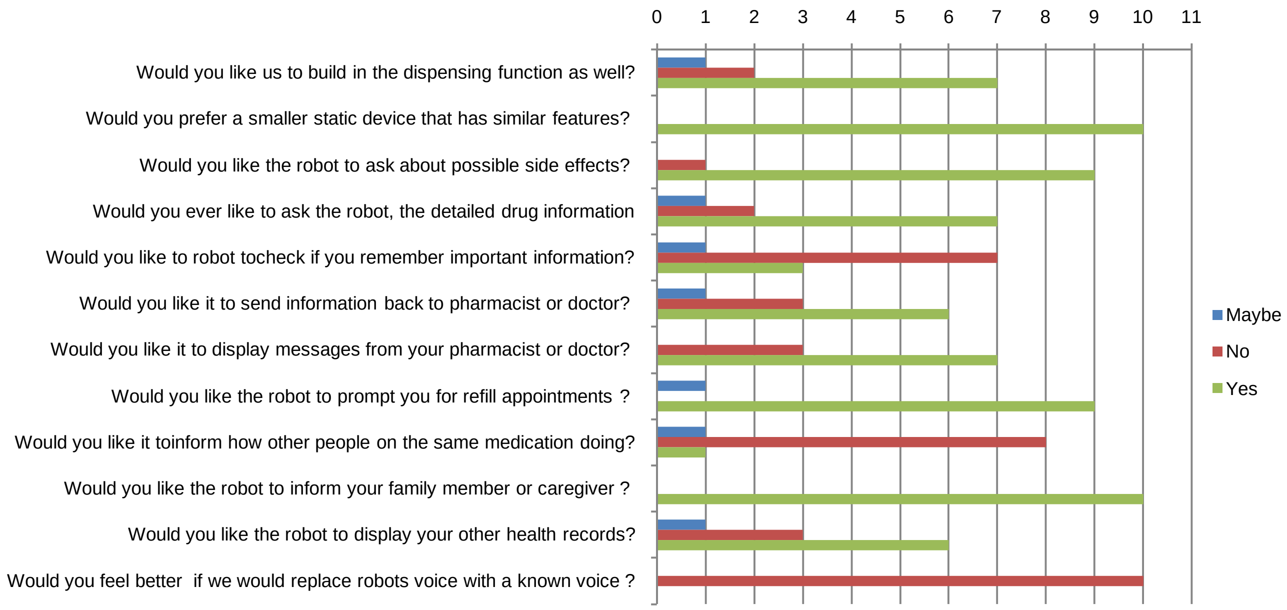

Figure 5 – Analysis of interview questions

X Axis represents number of respondents, Y Axis represents the questions asked

The reason might have been to retain the subservient connotation of a mechanical device, which needs to be studied further.

5 Discussion

This study was conducted in the context of medication management to take advantage of preference for self determination and independence of making choices in relatively independent aged care facility residents, at the same time addressing issues around compliance and safety of medication use.

Reviewing the literature around quality use of medication in the elderly several issues are highlighted. It is easy to delegate a passive reminding function to a talking pill box or automated dispenser, but they are not sufficient to enable engaging interaction, provide detailed instructions/education, invoke affect and social support, build trust by addressing safety, troubleshoot errors, and report and call for human help in real time – functions which many older people often need. By virtue of its mobility, anthropomorphic presence, wireless connectivity and an empowering mixed-initiative user interface, a robotic platform offers potential opportunities that were not possible earlier with simple standalone reminder devices and pill management systems..

The use of a touch screen interface supported a well structured dialogue sequence that enabled timely and personalized medication reminding. The medication administration process traditionally follows the “five rights”- right medication, right time, right person, in the right dose and by right route (Julianne and Terri 1996). By reading current pharmacist dispensing data we promoted consistency between dialogues spoken by the robot and the dispensed medication. Many times the prescribed medications are substituted by the pharmacist (e.g. branded to generic) or changed after discussing his concerns with the prescriber. A discrepancy between the medication name “being displayed” and medication “in hand” could provoke significant anxiety and user dissatisfaction. Therefore dialogue for reminding specific medications needs to be carefully designed.

A user recognition system backed up by self confirmation of identity provided assurance that the robot is interacting with an authorised person who has specific set of medications at the time of interaction.

The time of interaction (breakfast, lunch, tea and bedtime) was read from the pharmacy data and reconciled with the scheduler application that carried date and time functions. However the data was incomplete to ensure we could parse individual medication (e.g., ‘empty stomach’ and ‘with food’ medications are taken separately despite both potentially being prescribed for breakfast time) and needed manual correction. Also the information on medication forms (pills, syrups etc.) and organization (packaged or loose medication) was missing. These variables would need finer grained customization.

The users were prompted to read the labels and confirm (by matching it with the prescribed instructions on the screen) if they got the right medications. On the one hand, we thought that prompting to read labels would offer cognitive exercise instead of promoting passive dependence on an assistive technology (and was appreciated by competent users), however on the other hand it proved challenging for people with cognitive impairments. Probably we need another layer of customization that prioritizes dialogues according to cognitive status and takes advantage of pre-packaged dispensing systems for challenged users. We also found that often people bypass compliance with the instructions of taking their long term medications (e.g. rinse your mouth after oral steroid puff) but detailed description at each instance of reminding could encourage the right behaviour. In this study it was observed that people were reading instructions more carefully and commenting “*Oh I never read that one before*” but further video analysis is warranted to categorise some of the patient behaviours (e.g., the learning about this fine grained observation of adherence to best practices).

The system also enabled a user to refuse compliance to medication at any given instance. It did try to probe a bit deeper into the reasons of refusing to take the medication in order to determine if the user was not feeling well or the medication was being perceived inappropriate. This has important implications in terms of the need to inform a human caregiver (if user agrees to it) for safety reasons, but also to inform the prescriber if prescribing behaviour needs to be modified to suit individual preference. This was seen as an important step because medication non-compliance tends to be as high as 60% in older people, the reasons for which are poorly understood (Van Dulmen et al. 2007). This function was intended to improve our understanding of the phenomenon of non-compliance in the elderly so that refinement of strategies could be informed.

Ability to complete the interaction (albeit with assistance in the case of this first feasibility study) and reporting high on user friendliness of the system supports our hypothesis that older people can successfully navigate through a touch screen based system to assist them with a complex self-care task (i.e. medication intake). Perhaps the most useful insight came from observing a respondent who was cognitively impaired but was able to complete the interaction with progressive improvement in performance. This behaviour suggests the possibility that the use of robots may enhance cognitive performance and could train users for skill building, instead of making them more dependent on assistive technology. This needs to be studied further, but has wide implications for use of technology in elder care.

On the down side, we underestimated the limitations of passively parsing the pharmacy data to inform the dialogue process and the need to customize it in a finer-grained manner. We also failed to address null values and system failures where we assumed that all interactions would proceed smoothly. It is essential to resolve ambiguities in the face of missing data or system failures to avoid confusing vulnerable users. This leaves our engineering teams with issues to address and to resolve in the next iteration of the application.

The research also points towards the future development of applications by reflecting the users' strong desire for issuing refill reminders, keeping family members and caregivers in the loop, minimizing obtrusiveness and for development of modules for active screening of side effects.

This is probably the first time touch screen based robotic applications have been studied in the context of medication management for older people. The study informs that application of user interface design principles mentioned earlier in the paper, and can make it easier for older people to manage complex tasks. The study also points the direction with respect to where errors may happen and prompts us to seek better ways of resolving them.

The implications discovered in this study are limited by the small number of respondents, lack of randomization and the partially researcher supported interaction. However, the feasibility study has informed us to be better prepared for a larger scale trial. The next stage of our research project will focus on a trial of longer exposure of ACF residents to the robot.

6 Conclusion

This study investigated the feasibility of use of a touch screen based robotic system by older adults and analysed their interaction in addition to eliciting their opinions and suggestions around medication assistance. The older adults could complete the tasks successfully, felt confident while using the system and actually found it easy and simple. Although there was a large number of errors, most of them seem possible to be addressed by making the application more robust, particularly in terms of capability to resolve ambiguities around missing information items.

Further studies should consider a robot with built-in medication dispenser and with more intelligent dialogue design (e.g., more ability to seek clarification of unexpected situations such as users reporting medications at variance with the electronic record). They should also be conducted on a larger sample size with random selection of users who are minimally supported or prompted to elicit subtler usability issues. There is also an opportunity to explore a wider range of applications that exploit the user friendliness of touch screen based automated dialogue systems in healthcare.

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