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Feasibility and Acceptability of Smart Augmented Reality Assisting Patients with Medication Pillbox Self-Management

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Abstract

Complex prescribed medicine regimens require extensive self-management. Handling multiple pills can be confusing; using a pillbox organiser is a common strategy. A smart Medication Coach Intelligent Agent (MCIA) can support patients in handling medicine. The aim of this research was to evaluate the feasibility and acceptability of the MCIA. A prototype was tested with 15 participants, age 17-76, filled a pillbox according to prescription assisted by the MCIA implemented in a Microsoft HoloLens. A quantitative method using questionnaires was applied. Results showed that using the MCIA implemented in an AR-headset, to assist people with prescribed polypharmacy regimen in filling a pillbox, was feasible and acceptable. There was a difference related to age regarding people's willingness to use an AR-headset for medication self-management. People older than 65 felt less comfortable using the technology and were also more hesitant to use the technology than those under 65.

Keywords:

Self-Management, Artificial Intelligence, Polypharmacy

Introduction

For people with chronic disease and multiple prescribed medications, self-management is considered an essential component [1]. Self-management requires an active role of the patient, including managing symptoms and medical treatment on a daily basis [2]. Using multiple medicines is commonly referred to as polypharmacy and is more common among older people [3]. On average persons older than 65 years have three chronic conditions, and more than 70% take five or more drugs every day. For patients with coexisting conditions, who take multiple prescribed medications distributed throughout the day adherence can be particularly challenging [4, 5].

Adherence to medication regimens is key to achieving better health outcomes for patients. Nonadherence to prescribed medication affects both the quality and length of life for patients [6]; it also places a significant cost burden on healthcare systems [7].

Common strategies used by older people to improve adherence to polypharmacy treatment is to associate medications with specific daily routines, such as meals, and using a pillbox [2, 8]. Instead of taking pills from multiple packages at different times throughout the day, the pillbox is filled up for a week at the time. A pillbox commonly has 28 compartments, distributed as seven horizontal compartments labeled Monday to Sunday, with four vertical slots for each day. The vertical compartments

have labels suitable for the most common times to take pills during a day, such as morning, noon, evening, and bed.

Handling one's pills and filling the pillbox is part of medication self-management. Complexity in treatment regimens can lead to difficulties for people to continue self-management related to taking medicine and filling the pillbox. Medicine pills that look similar and use of generic medications can cause confusion and insecurity which in turn may be the trigger point for why people are unable to continue self-management and instead need to apply for health care services and help from a nurse to fill the pillbox for them. With this situation, patients lose their independence. It also puts a strain on society and health care systems, as there in many countries is a growing shortage of nurses and other health care professionals.

Based on the augmented reality (AR)-paradigm and intelligent coaching systems, a novel solution has been introduced. A smart mHealth application that can support patients with common problems related to the management of their medication makes it possible to provide patients with assistance and give advice when filling a pillbox, thus enabling continuous self-management and delay or minimize the need for nurse intervention [9, 10]. This smart mHealth application is designed and implemented as a Medication Coach Intelligent Agent (MCIA). By Intelligent Agent, we mean a software program able to be reactive, proactive, autonomous, and social. Autonomy plays a critical role in the behavior of an intelligent agent since it is expected to take decisions on its own. Hence, the MCIA has to manage different types of information such as medication plan (medication regime) of the patients, medication restrictions, as well as the patient's preferences and sensor input data from an AR-headset. It has proactive and reactive behavior in order to support patients in medication management. The MCIA is implemented in an AR headset and has autonomous reasoning capabilities that allows it to lead with long term goals in the settings of medication plans [11].

An augmented reality (AR)-headset makes it possible to have the mobility of a mobile device and still establish a social and friendly relationship with the user in hands-free interaction. Through holograms, it is possible to augment the users' field of view with an avatar. With a digital avatar, there are more possibilities regarding looks and appearances compared with a physical robot, which might have more effect on the intentions of the users. An AR headset, such as Microsoft HoloLens¹, makes it possible to be more aware of the environment and user activities because of its many sensors.

The main difference between classic smart pillboxes and the MCIA is that the technologies provide support in different stages of the medication self-management process. Classic

¹ <https://www.microsoft.com/en-us/hololens>

smart pillboxes and smartphone apps generally target patient groups who need help with reminders of when to take medicine, supporting the patient at the time when the patient is to put the pill in his or her mouth. The MCIA may be used for this purpose. However, it can also support individuals at an earlier stage of the medication process, when they are filling up weekly pillboxes with pills from prescribed cartons.

The aim of this research was to conduct a pilot study to evaluate the feasibility and acceptability of the proof-of-concept prototype of the Medication Coach Intelligent Agent (MCIA), implemented in an AR headset. The prototype was tested in a living lab context where participating individuals filled a pillbox according to a prescribed polypharmacy medicine regimen, assisted by the MCIA implemented in a Microsoft HoloLens. We aimed to answer the following questions: a) Is there a difference, related to age, regarding if people are willing to use an AR headset for medication self-management? and b) Is there a difference, related to the experience of using smart technology, regarding if people are willing to use an AR headset for medication self-management?

This paper represents a follow-up to our previous research. Details regarding the development process of the MCIA and technical specifications have been described in previous publications [9]. Focus in this present paper is on the user perspectives.

Methods

Quantitative methods were used for data collection and analysis. The material was explored through descriptive statistics. The research presented in this paper was conducted as a multidisciplinary collaboration between community medicine, computer science and, artificial intelligence researchers.

Setting and Participants

The prototype was tested in a living lab context. The setting was a quiet and home-like environment. Convenience sampling was used, where persons in a medium size town were asked to participate in a study and test a digital tool with the purpose to assist individuals in handling medicine and filling a pillbox. Description of participants is given in Table 1. The evaluation involved 15 participants who were selected based on the following criteria: 1) Different levels of management of medication on a regular basis, 2) Wide range of ages (medication management applies to people in all ages, not just elderly), 3) Different levels of experience from using smart technology in general and 4) A mix of men and women.

Table 1– Characteristics of Participants (n=15).

Parameter	Value (n)	Value %
Age (years)		
mean (range)	49 (17-76)	
median	58	
Gender		
women	9	60
men	6	40
Using medication	8	53
Helping others with medication	1	7
Have experience using smart technology	8	53
Familiar with AR	4	27
Persons older than 65 yrs	7	47

Procedure

Initially, participants were informed about the test procedure, which was divided into 4 sequences: 1) Fitting of the AR headset, including adjusting the size and adequate positioning on the head. 2) Becoming familiar with using the AR headset. Participants were guided by the test leader to explore features in the AR-headset for the purpose of becoming acquainted with using command functions and the feeling of receiving information through holograms. 3) Performing the actual test, handling prescribed medicine, and act on information given in holograms. 4) Responding to the evaluation questionnaire. None of the participants had used or tried on an AR-headset prior to the test.

Functionality of the MCIA

The functionality involved displaying information about the prescribed medicine, thereby helping the user to select the right medicine and dispense pills in a pillbox according to prescription. The participants were able to use voice, vision, and gestures to interact with the system and were presented with both visual and audible output. Visual outputs were in the form of holograms. Output information showed whether the person had selected the right medicine and gave information about how many pills of that particular medicine to put in each slot of the pillbox.

Instrument

Data was collected through a questionnaire which was developed at Nordic Telemedicine Center, NTC: The questionnaire was intended to be used for evaluation of digital innovations developed through the NTC [12]. The instrument comprised totally 20 items, distributed as seven questions, Q1-Q7, regarding personal background information and the following 13 questions, Q8-Q20, were formulated as statements relating to participants' experience of using the MCIA. Responses for Q8-Q20 were on a five-point Likert type scale graded from value 1 (strongly disagree) to value 5 (strongly agree). The lower bound to agree was made at value 4 (4 or 5 = agree). Examples of statements are: "It was easy to understand the presented information," "I felt comfortable using the technology," and "I am willing to use this technology if it was available right now."

Acting on Information Given in Holograms

This section gives a description of the above-mentioned test sequence number 3: Performing the actual test, handling prescribed medicine and act on information given in holograms. During the test, the participant sat at a table. On the table was a sheet of paper with a list of prescribed medicines, an empty pillbox, and five medicine boxes with labels for the prescribed medication (Figure 1).



Figure 1– Illustrations of How the MCIA is Used in a Homelike Environment for Distributing Prescribed Medicine in Pillbox.

All participants used the same mock-up medicine list, while medicine boxes were original cartons from a variety of pharmaceutical companies. When the patient looked at a medicine carton, the MCIA interpreted and acted on the information, supplying the participant with instructions on how many of each pill to put in each compartment of the pillbox. If the participant looked at a medicine which was not prescribed, the MCIA gave information that this was the wrong medicine (Figure 2). The images processed were of the cartons of the prescribed medicine. Typically a carton contains several blisters. Blisters were not scanned as the primary target group for the MCIA are patients with adequate cognitive functions, but who need support and assurance regarding variation in pharmaceutical brand names and generic drug substances.

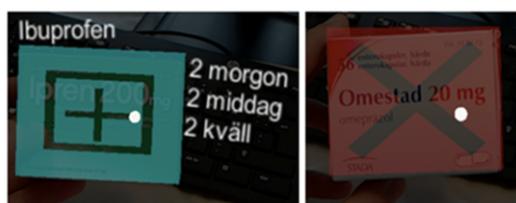


Figure 2– Visual Information From the MCIA, Presented as Hologram. Examples: (left) instructions on how many pills to put in each compartment of the pillbox and (right) message to not take the medicine.

Results

The results are presented for the sample as a whole and also for subgroups ‘Older than 65’ and ‘Have experience of using smart technology.’ This is done in order to be able to answer the research questions regarding if there is a difference in willingness to use an AR-headset for medication management related to age and people’s experiences of using smart technology (ST). Nearly half of the 15 participants (47%) were older than 65 years. A majority of participants (53%) had experience of using smart technology, and 27% said they were familiar with AR (Table 1). All participants with values 4 and 5 on Experience of ST were under 65 years old. Four participants older than 65 did have some experience of using ST, but they rated their experience lower than our cut off value (Figure 3).

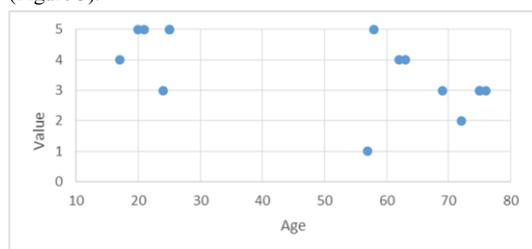


Figure 3 – Distribution of Response Values for Each Participant (n=15) for Variables ‘Age’ and ‘Experience of using smart technology’ (Values: 1=no experience and 5=very much experience).

Three of the 15 participants (20%) found it difficult to use the AR-headset, two of them were older than 65. The information was perceived as easy to understand (87%), and more than half of the participants (60%) felt comfortable while using the AR-headset to perform the medicine task. A difference related to age was discovered as all persons but one who said they felt comfortable using the technology, belonged to the younger age

group. None of the participants, from either age group, felt that it was stressful to use the AR headset. Regarding the functionalities of the MCIA, 40% preferred talking over using gestures while interacting with the MCIA and a majority, 93%, appreciated receiving audio output along with the holograms. Preference for talking instead of using gestures with hands was more common in the younger age group.

Participants were asked if they, given the technology was available and affordable, would be willing to use the technology a) in the future or b) right now. Also on these questions there were differences between age groups, where all in the younger group said they would use the technology in both scenarios while 50% of those over 65 gave the same response. Variables where differences related to age were discovered are displayed in Table 2.

Table 2– Variables Where Differences in Response were Related to Age, Comparison Between Groups.

Variable	Age < 65 n=8	Age > 65 n=7
Experienced in using smart technology	87%	0%
Feel comfortable using the MCIA.	100%	15%
Prefer talking to interact with MCIA.	42%	28%
Willing to use the technology right now	100%	50%
Willing to use the technology in the future	100%	50%

Discussion

Even though none of the participants had used AR-headsets before they did not feel it was difficult to take instructions from the MCIA to perform the task of handling medicines, and most of them felt comfortable. One aim of the research was to explore if age may be a factor related to whether people are willing to use an AR-headset to support medication-related self-management. Four areas were identified, where differences in opinion could be seen between the different age groups. Participants older than 65 years were more sceptical than those who were younger when it came to feel comfortable while using the AR headset, being willing to use the technology in the future and being willing to use the MCIA now (if it was available and affordable). This result may be connected to the fact that older people in society are among those with least experience of using digital technologies and have more reluctance to change routines [13]. They generally have not used digital services throughout their working life which is an area where people in most professions today need to use digital technology.

One surprising result in the evaluation was that it was the younger group who preferred talking instead of using gestures when interacting with the MCIA. Considering that playing video games using motion sensors, as featured by Nintendo, Playstation and others, have been part of everyday life for families with children throughout the last 15 years, it could be expected that younger persons would find using motion sensors to be an ordinary way to communicate with technology. In previous research with digital interventions for seniors to use social platforms with web camera instead of the telephone, to enable visual contact during conversations with family members, participants stated that they initially felt more comfortable with the telephone because they were used to it [14]. The initiative to develop the MCIA and pursue the evaluation originated from clinical problems and challenges

experienced by nurses and patients in rural home health care environments in northern Sweden. Having difficulties self-managing their medicine and pillboxes is a common reason why patients apply for home health care. With the current shortage of nurses, it is challenging for the health care system to deliver the services and new solutions are needed to support self-management and safe handling of pills [15].

Available on the market today there are several devices and apps featuring smart medicine reminders. Based on input from the initiators to this research, nurses, and patients in rural home health care, the main target group for the MCIA is not patients with cognitive impairment or those who need assistance with reminders when it is time to take the medicine. Instead, the MCIA is aiming to support individuals who unwillingly are forced into dependence on healthcare services because they feel confused and insecure when handling the variety of generic medicines they come across based on their prescriptions. To our knowledge, there are not yet any supportive technologies for this stage of the medication process or targeting this level of self-management.

Limitations

We purposely recruited to include a wide range of ages as medication management applies to people of all ages. With the results at hand, it became apparent that age-distribution among participants was distorted. Most participants were either young adults or retired. Aiming to explore the influence of age related to willingness to use technology it would have been beneficial if the sample also included middle-aged individuals in their 40's and 50's. A majority of patients in the target group for the MCIA device is likely to be found among persons older than 65 years [4, 5]. This was the reason for placing the divider between age groups at 65 years. However, due to the ongoing demographic development, it would be relevant to repeat this evaluation with all participants older than 65 and compare relevance of age between those older/younger than 80 [16].

Another limitation was the cut off where values 4 and 5 were used to indicate "agree." This level was chosen to limit the risk of false positive answers. However, this made it impossible to address the research question concerning if the experience of using smart technology was related to people's willingness to use the MCIA. Several participants in the higher age group had chosen value 3 and with the applied cut-off level they were treated as 'not having experience' which instead gave a somewhat false negative result.

Future work

In our future work, we aim to test the MCIA for a more long term usability evaluation. The evaluation presented in this paper was conducted with test persons in a living lab using mock-up medicine list, a future evaluation is planned in collaboration with a home healthcare organisation, where patients with polypharmacy treatment will test the MCIA AR device in their own homes based on their personal prescriptions. However, based on the results in this paper, the previously mentioned evaluation with participants over 65 needs to be conducted prior to the in-home tests.

Let us point out that the MCIA belongs to a new generation of autonomous intelligent systems that aim to take decisions of their own in order to reach their designing goals. The autonomy of these systems for taking their decisions is also giving place to new research questions about responsibility. For instance, to which extent does an autonomous intelligent system such as the MCIA need to be certified by law enforcement institutions in order to be used by end-users? To answer this kind of questions is out of the scope of this paper. But, we highlight that law

enforcement institutions will need to take an active role for certifying intelligent systems such as the MCIA. Let us observe that EU research projects, such as AI4EU, are appearing, and these research projects aim to develop new software methodologies that could guarantee transparency in the design and development of autonomous intelligent systems. In our future work, we will explore the social implications of the MCIA. In particular, to identify which kind of autonomous decisions by the MCIA that can put the end user in a risky situation will be part of our future work.

Conclusions

- We found that using the MCIA implemented in an AR-headset, to assist people with prescribed polypharmacy medicine regimen in filling a pillbox, was feasible and acceptable.
- There were differences related to age regarding people's willingness to use an AR headset for medication self management.
 - People older than 65 felt less comfortable using the technology.
 - People older than 65 were more hesitant to use the technology.

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