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Research paper



Elderly Experience Evaluation through Medication Learning Application with Augmented Reality

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Abstract

Technology advancement has been providing innovative solutions to assist elderly to overcome many challenges they face when learning about their medication due to their declining abilities. However, due to the lack of proper understanding of elderly experience and poor representation of their requirements, many of these solutions are rejected. Natural and simple interactions are one of the main features elderly require to adopt technology which can be supported through the integration of augmented reality technology with these solutions. This paper focused on studying elderly interaction with an augmented reality medication learning application and evaluating their experiences as a user from the perspective of visceral, behavioral and reflective levels at an early stage of the development process. The results indicated positive feedbacks with considerations when developing similar application for the future.

Keywords: *Augmented Reality, Elderly, Medication Information, User Experience*

1. Introduction

Elderly population has grown enormously during the last few years due to the advancement of science and medicine which increased people life expectancy [1]. The stage of elderliness is commonly marked by the retirement age and defined as the gradual weakening of ability with increasing vulnerability to disease [2]. These mental and physical changes impose limitation on elderly performance of daily activities including managing medication. The implications of these limitations are serious, as many elderlies are admitted yearly into hospitals because of issues related to medication managements [3]. Examples of the struggles elderly face when managing and learning about their medications are difficulty reading the leaflet due to poor vision, inability to identify the medication and forgetting the dosage and side effects. Unfortunately, despite the great capabilities and benefits these solutions offer, they fail to provide a satisfying user experience, jeopardizing their acceptance [4]. This failure is mainly caused by improper illustration of elderly real-life requirements including the lack of natural and familiar interaction between elderly and technology. This gap can possibly be overcome through augmented reality (AR), which merges the virtual objects into real-life scenes and offers a natural and smooth interaction between a user and technology [5].

In this paper, the requirements and design consideration for elderly and medication learning technology were explored. A study was conducted to understand the elderly firsthand experience when interacting with a medication learning application with augmented reality.

2. Literature Review

Elderly cognitive and physical ability declining makes simple daily tasks such as taking medication harder. The current medication management solutions offer great help to empower elderly people, but many fail to reach elderly acceptance mainly due to the lack of clear understanding of elderly real requirements [6]. Many researchers focus on evaluating a solution using quantifiable measurement from technology and outcome perspective neglecting the qualitative measurements expressing the experience of the user (Elderly in this case) experience [7]. A proper examination of the elderly experience will facilitate the development of an accepted and efficient technology to assist them. In this section, the concept of elderly user experience and its importance is explored. Secondly, the design consideration of elderly experience required to develop a medication learning solution is discussed. Finally, the area of medication management in general and medication learning solution is examined with the benefits of integrating AR technology with it.

2.1. Elderly Experience

User experience is defined as the responses triggered by using or expected use of specific product, service or system including physical, psychological and emotional responses [8]. Technical solutions promoting positive interaction yields a positive user experience [9]. Therefore, establishing elderly experience knowledge allows the development of successful solutions that address different needs including medication management. The notion is an umbrella of different psychological and social concept and not just a concept of usability [10]. Therefore, Yong aimed for a common framework to evaluate user experience [11]. His proposition was based on the Norman emotional design which consists of three levels: (a) Visceral level which focuses on the response triggered by physical aspects of a product such as colors and shapes; (b) Behavioral level which focuses on the usability of the product; and (c) Reflective level which examines the perceived image of the product with respect to the user's personality, preferences, beliefs and culture. This framework fits the need for early evaluation of prototypes to examine the user experience at an early stage.

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2.1.1. Design Consideration

Understanding the elderly experience is essential to increase their acceptance and bridge the gap between elderly and the solutions. This gap is created due to obstacles found on the elderly/technology relationship and the developer/elderly relationship. Attempting to overcome this gap, many researchers have proposed guidelines to adhere to before developing solutions that address the elderly. This matter can be examined from three perspectives which are User, Technology; and Interaction.

2.1.2. User

First, elderlies are known as one of the most diverse population in terms of their ability and preference [12]. Many developers find it hard to acknowledge this diversity and follow "Design for All" concept to ensure more users to their technologies. Nevertheless, considering the diverse nature, a single solution for all might not be appropriate and developer must cope with this diversity. Following design approaches that emphasis the user inVolvement such as User-Center design (UCD) would support the developer to understand the elderly and put their need, preferences and constrains as the main focus [4]. Moreover, rather than focusing on overcoming a disability through technology only, developers should make use of the elderly spare ability and empower them to enhance their own life. By doing that, the developer can overcome the elderly psychological frustration of technology caused by the fear of being perceived as passive and weak [13]. By putting themselves in the elderly's shoes, the developer could gain an insight on elderly need and mimic their ability [14]. Another consideration developers must understand about the elderly as users is their financial status. According to Alsulami [15], the financial barriers are one of the reasons that prevent elderly from purchasing assistive technologies. Therefore, the solution must be affordable for an elderly.

2.1.3. Technology

Looking at the matter from a technological perspective, the developers must avoid creating technology barriers while attempting to solve the elderly struggle. One of the technology barriers that might arise is the lack of clear perceived ease of use from using the technology compared to the traditional solution [15]. The elderly might assume the difficulty of the application due to the lack of knowledge on technology in general [16]. In addition, the elderly also have concerns on their privacy of the collected information, the safety and reliability of using the technology. All these aspects might create technology frustration preventing the elderly from accepting the technology. Moreover, many elderly resist using aiding technology worrying from the social stigma it might create where it identifies them as being "Old" and "Weak" [4][17]. Therefore, the technology must be invisible, unobtrusive and embedded within the elderly environment to decrease the effect of stigmatization. Additionally, developers should emphasis on the perceived benefit as solutions that focus only on tackling health problem often fail due to the negative association with the social stigma. Moreover, elderly mostly follow specific routine and schedules. Therefore, developers should aim to increase mobility and avoid restricting the elderly movement, and the technology should be context-aware and response to changing user actions and adapt to elderly natural paradigm [13].

2.1.4. Interaction

The Interaction perspective looks at the elderly and technology interaction. Elderlies are known as "Digital Immigrants" as they were born prior the technology era [8]. Therefore, low computer literacy is common among elderly which causes higher anxiety when interacting with technology. While moving a cursor, enlarging a window and clicking a button seems basic and spontaneous for younger generation, it might not make sense to some elderly. In another word, the technology should be accessible and match the elderly physical and cognitive abilities [14]. The developer should rely on natural interaction as much as possible to make the interaction between technology and elderly familiar and ease elderly anxiety toward technology. If new paradigm is necessary, special training sessions should be offered to the elderly such as the use of voice and gesture interaction. In addition, a solution relying on multi-mode interaction (e.g. the use of text and audio) stimulate the elderly cognitive ability and help them maintain their cognitive health as long as possible [7]. Moreover, developers should avoid the use of congested interfaces which might leave the elderly overwhelmed due to their affected navigation and cognitive abilities and the interface should be simple and clear as possible [18][19]. Another point developers must consider is that interacting with technology should encourage social integration and not cause any social isolation that elderly are prone to [9]. These considerations and the importance of elderly experience could potentially bridge the gap between the elderly and technology and facilitate the development of a successful medication management solution.

The process of developing an accepted technology should start with evaluating the user requirements and needs through different methods then creating a prototype directed by the end user feedback [9].

2.2. Medication Learning

The gradual weakening of elderly ability affects their capability to handle their medication. They might suffer from poor vision making it hard to distinguish the medications by labels or read the leaflet. In addition, they might find it difficult to remember the dose and schedule due to their memory weakening. Any attempt to overcome this struggle will not just protect elderly but will also increase their quality of life by making them more independent and engaged in the technical reVolution [20][21]. Many technologies attempted to overcome these struggles. Medication management technologies mainly falls under two categories based on their purpose which are; (a) Facilitate medication learning which includes reading the labels and leaflet; and (b) Improve medication adherence through reminder and monitoring [18]. Some existing solutions focus on assisting one category such as the AraMedReader which supports visually impaired users to retrieve information about medication [22]. Other solutions cover both categories such as the Spanish pillbox app [3] and the Medication Assistance application [23] which provide information and improve adherence. Researchers studied user perceptions on medication applications and indicated that elderly preferred two applications; one for adherence and one for information rather than one complex application that integrates both application types features [18]. In addition, mobile technologies deliver higher interactivity at a reduced cost than the traditional methods as already many elderly own a mobile phone [24]. Therefore, shifting from paper-based information (medication leaflet) to digital format could increase the accessibility to the information.

Augmented Reality (AR) enhances the surrounding environment by embedding virtual object in the natural scene and allowing them to interact with each other through an interactive visualization system [17]. Merging virtual objects with the surrounding environment improves the user perception of it [25] and enhances the interaction with the infrastructure design [26]. All of these potentials of augmented reality might assist medication management solution technologies to improve elderly experience [27] and overcome the adaptation barriers to reach elderly satisfaction.

3. Objectives

The objectives of this research are as the following:

- To understand elderly experience as users and the design consideration to be taken when developing an application which will support them in learning about their medication?
- To design a prototype of medication learning application with augmented reality.
- To evaluate the medication learning with augmented reality prototype with the potential users from user experience perspective.

4. Research Methodology

This research was based on a prototype where the prototype development followed the cycle of requirement elicitation, design, development and evaluation. Following the User Centered Design (UCD) concept, elderly participants were inVolved in all stages of development. The study used a combination of qualitative and quantitative techniques including observation, semi-structured interviews, focus groups and questionnaire. In addition, the user feedback elicitation process was optimized with the use of persona. The persona has been used in explaining the need for the proposed solution and make the elderly more open to share their knowledge and opinion The persona was of an independent 60 year old woman who is diabetic which affected her vision. She manages her medication and her husband medication and is well educated.
After evaluating the user requirements A high-fidelity prototype was produced following the user feedbacks as recommended in [9]. The prototype was a workable version but was still not finalized as the aim of this research was to capture the elderly experience in an early development stage.

5. Theory

This research is a formative exploratory research that aims to understand the possibility of integrating augmented reality technology to medication learning application to enhance elderly medication information learning experience. The initial requirements to medication learning application integrated with AR for elderly are as following: (a) The application interface should be very simple and provides minimum navigation and hierarchy; (b) The application interface should be clear and readable and support Arabic language considering that the targeted user are Arabic speakers and only few can understand English; (c) The application should support multimode interaction; and (d) Application should support independence as possible. These requirements were gathered based on the literature review and through a focus group session with a group of elderly and caregivers with a low fidelity prototype.
The application was an android mobile based application developed via Unity7 platform using Vuforia 6 SDK 6.2 tools to implement the augmented reality. The application was designed to detect a QR marker attached on a medication and play a corresponding video of a doctor explaining the medication usage, dosage and side effects in a simple and formal Arabic language. The use of QR provided many advantages as it can be easily generated in a large quantity, the use of it can extended to other purposes and not just as a marker for the augmented reality i.e. for providing other form of information; and provides fast detection due to its details and contrast. The application also allowed for a customized video recording if requested (see Figure 1).

6. Testing and Analysis

The evaluation of the application was based on Yong [11] proposed framework. The user experience was examined from three levels: (a) Visceral level; (b) Behavioral level; and (c) Reflective level. First, the evaluation focused on the elderly visceral interaction and response on application physical characteristics such as the sounds and display. Then, the elderly responses on the usability aspect of application such as the task completion time and how he behaves during the interaction were captured. Finally, the impression left on the elderly after trying the application and the reflected image and perception were evaluated.

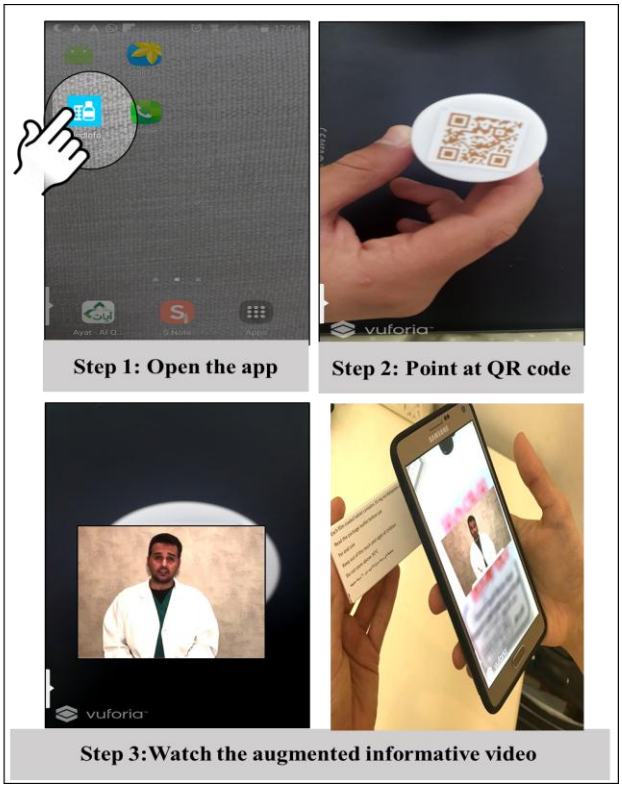
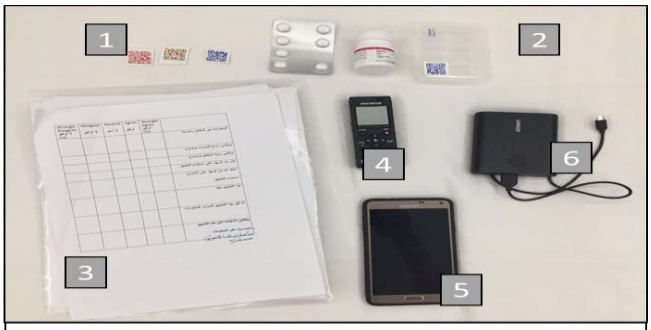


Fig 1: Demonstration of the Medication Learning Application with Augmented Reality.

The session consisted of one-to-one interviews with each participant. First, the participant was handed a participation information sheet explaining the purpose of the evaluation and a consent form to sign. After that, he or she was given the mobile where the application is installed and two different medications packages and one medication organizer and asked to open the application and detect the markers on the packages, so the pre-recorded video could be played solely by the participant without any guidance from the interviewer. The medication container marker was used if the participant wanted to record a new video. The time taken to detect the marker was recorded. After that, the participant was given a 5-likert scale questionnaire (from Strongly agree to Strongly disagree) with eight statements to fill (see Table 1). Finally, they were asked to give their feedback and comments. For the list of the materials used, see Figure 2. All required documentation including the consent form, the participation information sheet and the questionnaire were provided in the Arabic language, as the majority of the participants do not understand English clearly. In addition, the interview was conducted in Arabic and English phrases and terms were avoided as much as possible to avoid any negative impact and confusion. Moreover, the sessions were audio recorded based on the participants' preferences as video recording was not possible due to cultural and personal barriers.

Table 1: Questionnaire statements

Corresponding statements.	Experience Level
The information in the video was clear	Visceral
I was able to hear the video clearly	
I was able to see the video clearly	
It was easy for me to use the application	Behavioral
I think it will be easy for other users to use the application	
I think this application is useful	
I can trust this application as source of information	Reflective
I will use this application in the future	



(1)QR codes. (2) Medication package and organizer. (3) Questionnaire.(4)Audio recorded.(5)Mobile phone. (6)Portbale charger.

Fig 2: Material used to conduct the Evaluation

Recruited elderly were all above 60 years old with either normal or with very mild dementia who did not need a guardian consent to participate. Moreover, the sample recruitment targeted elderly living in their own house or with relatives. None of the participants in the focus group for the low-fidelity prototype were recruited for the high-fidelity.

Twenty persons participated in the evaluation. Their age ranged between 60 and 82. The participants were four males and sixteen females. The education level varies as two were PHD holders, two held bachelor degree, one with high school degree and the remaining did not finish a formal education but can read and write. None of the participants work in the medical field to avoid any biased data. All the participants Volunteered and were recruited through social media, word-of-mouth and announcements. The sessions were conducted in a quiet and proper-lighted room to avoid any disruption that might affect the results. The locations of the evaluation were chosen based on the participant's preferences. Figure 3 demonstrates the setting of the evaluation session.

The data collected were audio records of the sessions, observation notes, participants' questionnaire answers and comments. All data were first translated to English then unitized and categorized under three themes corresponding to levels captured during the evaluation; for example, "participant could not hear the sound" was linked to visceral level while "participant asked to be told when the application is published" was linked to reflective level.



Fig 3: Participants were given Minimum Assistance During the Evaluation to Evaluate Their Ability to use the Application Independently.

7. Results and Discussion

The data gathered from the evaluation was in written and audio form. Two participants refused to be recorded therefore their feedback, interactions and answers were noted down. After analyzing the data, the results were categorized under three themes corresponding to the experience level.

First, several observations were noted during the participants' interaction with application. Only six participants were able to detect the target the first time. Participants with a shaking hand found it difficult to detect the target as the camera was not stable. In addition, the concept of detection was new for some participants as they imitated bar scanning by making the phone's camera touch the target rather than just pointing at it. Also, some participants refused to try without having a demo first by the interviewer. Placing the medication in a table rather than carrying it in one hand and the phone in the other hand was more convenient as it gave the participants more support to hold the phone steadily. It took the participants an average time of 15.8 seconds to complete the first try while it took them an average time of 9.3 seconds for the second try, showing the effect of learnability. It was also noticed that many participants were more willing to be expressive after discussing the persona.

Second, the questionnaire results indicated that the application left a generally positive experience. For the video understandability and audio clarity, 90% agreed and strongly agreed that it was understandable and clear. Yet, 15% had trouble viewing the video. For the ease of use, only one disagreed and found the application uneasy yet six participants thought it would not be easy for other elderly to use and other six were neutral. Two participants hesitated about whether they would trust the application as a source of information and other two remained neutral (see Table 2).

Finally, the brief interview conducted after the questionnaire provided more insight on the participants' interactions and responses. Regarding their visceral experience, one participant noted that the name of the medicine should be very clear while another one pointed that the video should be made longer. One participant expressed their need for more familiar language that they can understand. Additionally, regarding the hesitation of performing the first task individually without assistance, one participant expressed his fear of breaking the phone or ruining the application. On the usability and behavioral level, some participants suggested other uses of the application that they would benefit from as one stated:

"It is useful to know if I have this medication or not (she is looking for) rather the bringing new one while one already is in the medication cabinet" 64-year-old female.

"*I don't open the medication leaflet… I need it when I have a medication that I have not been using for a while*" 63-year-old female.

While other participants expressed the advantage they see comparing to the traditional way they use. According to one participant:

"*It is useful! I use reading glasses, but I still cannot..., I have to beg them (her family) to read the prescription, I want to read the medication leaflet, but it is tiring!"* 70-year-old female.

In the contrary, one participant did not see the benefit of the application as he stated:

"*In my opinion majority of patients rely on what the doctors say, try the medication for a week and then they get familiar with it…If patient should know everything, what is the role of the doctor then?"* 82-year-old male.

Expressing the reflective experience, the application left on them, one participant disagreed with both statements and explained that he needed more detailed information. He stated:

"*I don't even buy over-the-counter medication due to my health condition, even if doctor prescribed it for me I have to thoroughly research it. But for others who don't do so, I know it (the application) is very useful for them"* 62-year-old male.

Moreover, some of the participants who agreed that the application is trustworthy conditioned that with it being authenticated from a medical party and narrated by a doctor. On the contrary, another participant wanted to have the option to narrate the video herself since she knows what she need better. As she stated:

"I would like to record myself because I know what benefits me and what their side effects on me" 70-year-old female.

Table 2: Participants' Responses on Questionnaire

	Strongly Agree	Agree	Disagree	Strongly Disagree	Neutral
Understandability	12	6	0	1	1
Audio Clarity	12	6	1	1	0
Video Display	14	3	3	0	0
Ease of use for participant	14	4	1	0	1
Ease of use for other users	5	3	6	0	6
Usefulness of the application	13	5	1	0	1
Trustworthiness	13	3	2	0	2
Motivation	14	4	2	0	0

The indicated results shed the light on important themes that should be considered when developing elderly supporting application integrated with augmented reality. First, the application left a general positive experience on the elderly. The participants were willing to adopt the application and adopt augmented reality once the benefit has been demonstrated for them. Hence, the technology anxiety can be overcome through a proper introduction and emphasis on its usefulness and simplicity [16]. Demonstrating this statement is a comment from one participant who stated:
"If that's it, it is very good!" 68-year-old female.
Yet the reflective level evaluation directed the attention of the trustworthiness of the application. Considering the delicacy of medication information, the application should be authenticated from a medical party and gives a customization option for users who prefer to record the video by themselves. Another consideration that should be taken is the language and terms used whether audio or written. The available options for the narrator are: medical personnel, caregiver, or the users themselves (the elderly). While medical personnel increase the credibility and safety, the use of medical jargon and the concerns of the efficiency for the personnel in terms of workload and the need to customize some prescriptions according to each patient's needs must be considered. On the other hand, if the narrator were the caregiver, it would provide emotional support and connection in addition to the use of a familiar language. If the elderly narrated the video themselves, it would improve their confidence and self-esteem as they become an active user and it would provide memory practice. Nevertheless, if the narrator was either a caregiver or the elderly, additional training would be required, and the information recorded are prone to error (see Table 3).

Table 3: Comparison between Options of video Narrators

Video Narrator	Advantages	Disadvantages
Elderly	Improve confidence and self-esteem Memory practice More active role	Needs training
Caregiver	Emotional support Familiarity and simple language	Error possibility
Doctor	Trustworthiness Standardization	Difficult language Efficiency for doctors Generalization

The second theme is the ergonomic aspects of this type of applications. Considering elderly's low vision and hearing, the lightening and the sound of the video should be enhanced. Moreover, the video should be supported by visual images of the spoken instructions to increase the understandability through multimodal interaction (audio and visual). Additionally, any augmented reality application should emphasize on overcoming the shaking hand obstacle which disturbs the tracking through enabling extended tracking which allows the augmented scene to remain on the screen seconds after the loss of the tracked target (QR in this case). Also, the use of marker-less tracking where the target is the object in itself (the medicine) and not a marker (QR code) could help overcome this obstacle, yet the issue of efficiency and robustness in the marker-less augmented reality should be addressed. Another possible method to enhance tracking is the use of text recognition to identify the medication through its label. Nevertheless, the text specifications (font and size) on medications box are not standardized, neither is their placement on the package. Another issue is that many elderlies remove the package or rearrange the bills in organizer containers. Therefore, there are many scenarios that should be addressed for an accurate and efficient tracking and detection using text-recognition method. Finally, in similar application that supports elderly using augmented reality the use of mobile phone was efficient considering its low weights, cost effective, allowed freedom to move one hand and provided direct view of real world.
The final theme that was highlighted during the evaluation is the inVolvement of elderly in development process. While elderly inVolvement is crucial to meet their requirement, there is some consideration to note to optimize the benefit of their inVolvements. First, it is important build a confident and trusting relationship between the developer and the elderly, so they can share their thoughts freely. The words used during the process should link it to an experience the elderly knows and is familiar with. It should be simplified according to the elderly background while avoiding patronizing them. Developer should try to avoid linking a negative aspect to the elderly directly. For example, while the majority of the participant agreed that they would easily use the application, their hesitation was only noticed during the fifth statement where the difficulty was assigned to others, which gave them more freedom to criticize the application and point out some possible enhancement. The use of persona and possible scenario also provoked the elderly contributions. Moreover, considering the elderly diverse nature, the diversity of the elderly participating in the development process is important to capture different experiences, which enhances the accepting rate among elderly when the application is finalized. Finally, the use of both qualitative and quantitative approaches (i.e. questionnaires, interviews and observations) provided a comprehensive knowledge of the elderly experience and optimized their inVolvement.

8. Conclusion

Medication learning is a vital task many elderly struggles with. Despite the advanced solution offered by technology, many elderlies are not willing to adopt them fearing the poor elderly experience when interacting with them. Augmented reality endorses natural interaction which enhances the user experience. This study aimed to understand elderly experience firsthand by developing a prototype of a medication learning application that was enhanced by augmented reality and evaluate how the elderly interact with it to examine the consideration and potentials for such a solution. The evaluation yielded a generally positive experience with the important theme to emphasize on for the future including the ergonomics, possible enhancement and the elderly inVolvement in development process. It could focus on the technology quality aspect in addition to implementation in a large-scale process. Concerns of content provider and the medium for distribution should be resolved to expand it as it benefits on a larger scale. In addition, the augmented reality could be further utilized in other features such as indicating the expiration date.

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