Intelligent Pillbox: Evaluating the User Perceptions of Elderly People

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Abstract

Pillboxes represent a good solution in the adherence to medical prescriptions for elderly people. They are built taking into account aspects as ergonomic criteria, several doses of medicine and another consideration about their design. Therefore, we have presented a pillbox prototype which helps elderly people in taking all doses of medicine. This paper presents the next step towards a useful device, here is presented an empirical evaluation of the "Intelligent Pillbox" by using the Technology Acceptance Model to evaluate the ease of use perception, usefulness perception and intention to use in the future of this new technological device. The evaluation consists of a quasi-experiment which was performed by 45 elderly people, who attended to institutions focused on work with this priority group in several integration activities. Results show positive perceptions of this solution that indicates the intention to use in the future and provide us insights about possible improvements.

Keywords: Empirical Evaluation, Intelligent Pillbox, Elderly People, TAM, Technology Acceptance Model.

1. Introduction

Pill organizers and pillboxes are shown as important tools to improve medication disorders or adherence mainly in elderly people, several developments about these devices have been presented and patented; moreover a lot of research has been developed by the academy and industry in this area [1]–[4]. In Park [5] is shown medical adherence as an important issue in the health behavior. Moreover, it is strongly influenced by the correct taking of medication, as it is prescribed. On the other hand, if people do not take medication on time and correctly, they become non-adherent patients [5]. A target that needs help to be adherent is precisely elderly people because they are part of the priority groups in medicine, because of their

disabilities due to their age and cognitive disorders [6]. In a study from World Health Organization (WHO), which involves various countries, it has been determined that approximately one half of the total drug consumption is formed by people aged over 60 years [7]. With these preambles, developments as pillboxes or reminders support tackling with the problems of non-adherence to medical treatments.

Most of the time, there is not enough evidence about validation of devices from a technical perspective. However, in order to show the feasibility of developments and users perceptions, it is necessary to prove the new solutions from a qualitative and quantitative perspective. Therefore, empirical validation, which addresses the perceptions of users is important for developers of this kind of devices due mainly that it can let them know the acceptance and correct functionality perceived from the point of view of the real stakeholders.

The "Intelligent Pillbox" prototype was presented by Parra et al. in [8], in that paper is presented the architecture, design and prototype, a technical validation of this device. Then, as a second step this paper presents an empirical validation since the user view point and their perception about the perceived ease of use, perceived usefulness and intended use in the future of this pillbox when it is used by an elderly person. Therefore, evaluations have been performed in institutes that are involved with elderly people, which represent the pillbox target. The validation model used is the TAM, developed by Davis (1989) [9] which is directed to evaluate the parameters to evaluate the perceptions of the pillbox users.

Measure perception through empirical validations form a great part of several studies, because the development of solutions is not only important but also necessary to prove their user acceptance [10]. Hartwick [11] emphasizes the increasing importance of theory testing for technology research, for which the evaluation of existing findings and solutions is desirable, particularly when the findings involve different technologies, and user populations contexts. In Selim [12] is presented an empirical validation by using TAM (Technologic Acceptance Model) about the perceptions of learning online websites in a group of students. This study concludes in a perception of these websites as efficient learning tools. Another validation using by means of the use of TAM constructors to evaluate perceptions is presented in Hu [10], here the target evaluated were physicians and medical specialists to examine acceptance of telemedicine technology in treatments. This study concludes a good acceptance of methods; however, users perceive as difficult to use because of a lack of an efficient connection between participants involved in the digital medical infrastructure. Therefore, TAM models can be applied in technology approaches in order to provide insights about user perceptions to improve new developments.

The goal of this quasi-experiment is formulated from the problem to be solved viewpoint by following the GQM (Goal-Question Metric) method proposed by Basili *et al.* [13]. Therefore, this paper presents an evaluation from the user perspective to evaluate the user perceptions of a digital pillbox. This device mainly was developed to improve medication schemes in elderly people. The pillbox considers two actors: 1) on the one hand the keeper/doctor who configures and distributes the doses and pills in the pillbox and 2) on the other hand, the patient who uses as a reminder this solution. The former is one who configures dosage schemes and fills with the device with the pills; the second one is the elderly patient who is alerted by means of alarms or lights about the doses that should be taken. In this case, the objective is to evaluate the perceptions about the use of the pillbox.

The structure of this paper is: section two analyzes related work, section three presents a brief explanation about the intelligent pillbox to be evaluated, section four shows the experiment design, and section five presents the evaluation of the prototype. Finally, section six presents the conclusions and further work.

2. Related Work

Before developments as pillboxes, studies were dedicated to identify problems of traditional drug therapy in the elderly, as is presented in [5], [7], [14]–[16]. In these studies, three main factors were involved: patients, prescribers, and drugs. i) Patients have multiple pathologies and diseases which can be treated with a prescribed regimen. This regimen can be supplied

poorly as age increases. ii) Prescribers, can have an inadequate way to teach elderly people about how they should take their doses in a medication schedule. And iii) drugs which can present problems as alterations in drug kinetics, dynamics and interaction between them [7]. Problems and studies about medication in elderly people have given important parameters to improve this topic, mainly in adherence and discipline in treatments in this priority group.

In this section is presented a study about empirical evaluations applied to 1) technical developments, 2) traditional pillbox uses and 3) electronic pillboxes. These studies will give us insights about some metrics and values, which let us know about the state of research in this area.

Empirical validation is necessary to understand the behavior of users when using a new solution. Therefore, Morales [17] presents a study regarding the usefulness of pill boxes in dispensing and dosing medicines for therapeutic treatments of different health disorders in patients over 70 years. The process consists in measuring the response of a patient by using a pillbox. The result shows an improvement of 6.74% in the regularity of taking doses. Then, Hayes [18] presents the development of an electronic pillbox, which has been evaluated with 39 people (13 men, 26 women) between 75 and 85 years old. Here, in five weeks the patients, who live alone, used the solution and after that, they completed questionnaires about usability issues and benefits about the device. Here, only one subject reported difficulties in using this device; nevertheless, this study also highlights the improvement in adherence in their treatments while patients were using this solution [18].

As is shown in related work, there are studies which show approaches that evaluate solutions about user perceptions. Therefore, it is important to take into account the real needs of patients and their expectations related to the ease of use, usefulness, and intention to use the solution in the future, in order to create useful artifacts to provide health and benefits to the elderly.

3. Intelligent Pillbox Integral Operation

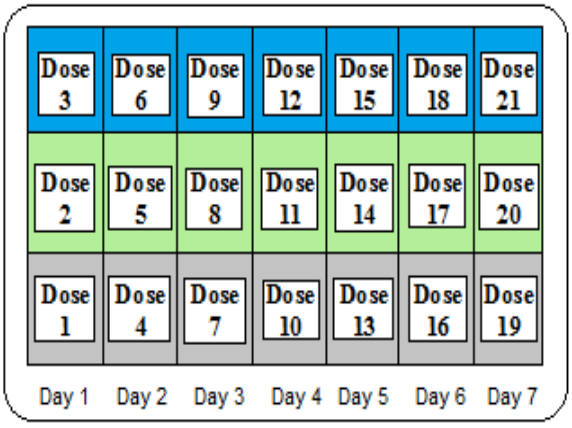
The Intelligent Pillbox is an Assistive Technology (AT) device whose development is focused in the support of elderly people and other vulnerable groups that may have needed for Assisted Care and the improvement of medication mechanisms. Thus, it allows dispensing several medication schedules, which are prescribed for health disorders common to elderly people [8].

The use of this device involves two phases: 1) Filling and programming the device: focused in doctor or caregiver's performance 2) Taking the medicines from the device: focused in the action of the elderly patient. *Intelligent Pillbox* was designed taking into account certain criteria that provide facilities in using, introducing and withdrawing the medication from this device. The design is presented in Figure 1-a). Then the distribution of compartments is shown in Figure 1-b). There are detailed twenty-one doses for one week with a daily total of three doses; however, the *Intelligent Pillbox* is flexible for any medication scheme linked to the patient.

Figure 1. *Intelligent Pillbox* and Doses distribution

a) Intelligent Pillbox

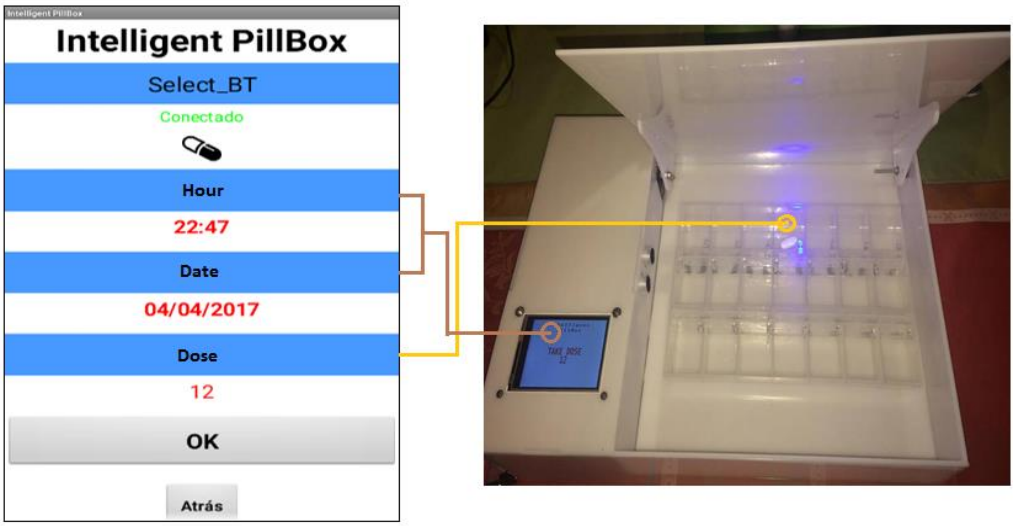
b) Doses distribution



In this device, the Arduino Mega 2560 is the main controller and it commands: i) a programmable alarm system with an automatic opening and closing system by using a servo motor; ii) an interactive user interface between an application designed to Android devices in the software MIT APP Inventor and a Bluetooth module inside the device; and finally iii) a notification system through the GSM network. Arduino, obtains the time from a Real-Time Clock (RTC) module, and it is shown by means of a LCD screen to the patient. It is possible to open the device through a password entered from the touch screen, then when the door is opened, it is possible to fill its compartments with the appropriate doses of medicine. After that, it is necessary to configure the dose for patient (e.g., the hour of ingestion, hour and dose number). This is possible by using the Intelligent Pillbox application (see Figure 2a). All this data is sent by Bluetooth to the pillbox. When it is dose time, the device notifies the patient through: an alarm, a LED light and a notification sent to cellphone or Tablet (Figure 2b).

Figure 2. Configuration of the Intelligent Pillbox

a) Programming Dose **b)** Alert of dose time.



4. Evaluation

In order to evaluate the acceptance of the *Intelligent Pillbox*, in this paper is presented a first approach evaluating patients (one of the final users mentioned of this assistive device) getting their perceptions and collecting a feedback. The Technology Acceptance Model (TAM), proposed by Davis [9] is a widely used theoretical model, from the perspective of general system usage. TAM presents three main constructors [9]:

- *Perceived Ease of Use (PEOU):* Degree to which users expect the target system to be effortless.
- *Perceived Usefulness (PU):* Probability that with the use of a specific application increase its performance in an activity.
- *Intention to Use (IC):* Measure of resistance to execute a specific behavior, it represents the user´s intention to make use of certain technological application.

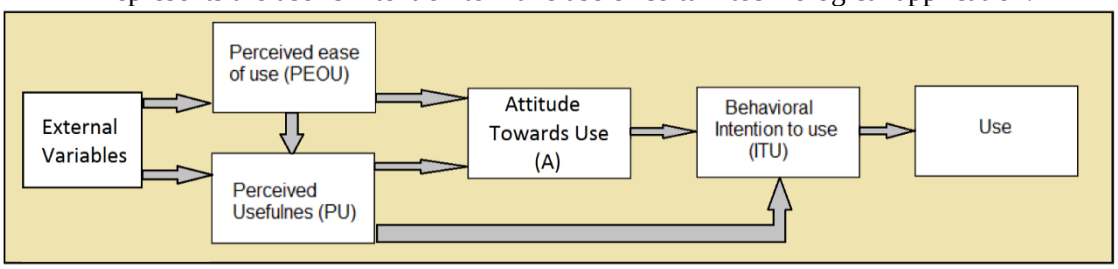


Figure No. 3 TAM Model Proposed by Davis (1989)

To develop this evaluation it is necessary to measure the variables that are based on the user´s perception, in this case, regarding the pillbox. It is necessary to define previously the hypotheses that allow us to verify if this contribution is accepted in practice, in the case of the Intelligent Pillbox. The hypotheses are focused on the constructors of the TAM model which are ease of use, usefulness and future intention to use:

- $H1_0$: Intelligent Pillbox is perceived as difficult to use
- $H2_0$: Intelligent Pillbox is not perceived as useful
- $H3_0$: There is no intention to use Intelligent Pillbox in the future
- $H4_0$: There is not a causal connection between the perceived ease of use and the intention to use the solution in the future
- $H5_0$: There is not a causal connection between the perceived usefulness and the intention to use the solution in the future

5. Design of the experiment

Based on a hypothesis proposed since the TAM model coupled Intelligent Pillbox, the validating process consists of negating each one of them. These items (i.e., PEOU, PU, ITU) linked to each hypothesis are evaluated through a questionnaire. It has 14 questions formulated to be answered on a scale of 1 to 5 points of Likert, assuming as neutral value the number 3, indicating this as starting point to evaluate an improvement or rejection of the contribution. The design of this questionnaire, presented in Table 1 is composed of five questions focused on PEOU, 6 questions corresponding to PU and 3 of them to ITU. In addition to this questionnaire, two open questions about suggestions to the device have been supplied (see Table 2).

Table 1. Applied Questionnaire

Question	Positive Sentence (5 points)
PEOU1	Has been the Intelligent pillbox difficult to use?
PEOU2	Overall, Is the mechanism of use of the Intelligent Pillbox difficult to understand?
PEOU3	Overall, do you consider the use of Intelligent Pillbox useful for remembering medication regimens?
PEOU4	Do you think that the setting of a dose and how the patient is reminded is useful for overcoming medication disorders?
PEOU5	If you need a tool to know if you have taken the medication properly, would you use this intelligent pillbox?
PU1	Do you think that using the Intelligent Pillbox, you will reduce the problems in taking medication?
PU2	Is this pillbox (operation of Intelligent Pillbox) easy to learn?
PU3	If you consider the use and purchase of a pillbox, would you take this solution into account?
PU4	Would the use of this artifact improve the disorder in taking medication?
PU5	Do you think that with the constant use, would it improve your ability to use this Pillbox?
PU6	Could you recommend the use the Intelligent Pillbox for taking medication?
ITU1	Do you consider that the use of the Intelligent Pillbox is not useful for taking medication mainly in the elderly?
ITU2	If you need a tool to improve the health by mean of medication, would you take it into account this solution?
ITU3	Would you recommend using this Intelligent Pillbox for taking medication?

Table 2. Questionnaire (Additional Open Questions).

Question	Open Questions (OQ)
OQ1	Do you have any suggestion for making this solution named Intelligent Pillbox easier to use?

OQ2	Why do you intend to use Intelligent Pillbox in the future?

5.1. Approach and Application of the Quasi Experiment.

As known the main goal is to evaluate the final user: patient, so the proposed Quasi experiment was developed with several groups of elderly people, who assist to the UAM (Universidad del Adulto Mayor - University of the Elderly) and to CAAM (Centro de Atención al Adulto Mayor - Adult Care Center), both of them are located in Cuenca, Ecuador. The total of participants was 45 people taken in groups of 7, 8, 10 and 20 people, over 65 years old (men and women), evaluated at different times, within the indicated centers, all participants having been introduced to the use of the Intelligent Pillbox. Thus, 18 people were evaluated in the morning and 27 in the afternoon at the centers afore mentioned.
Firstly, a preliminary demonstration of the use and operation of the pillbox was carried out by the Intelligent Pillbox developers for 10 minutes, during which time was shown to the potential patients (elderly) how the pillbox works and the alerts that the device has, alerting them at medication or dose time. In addition, a complete demonstration of the operation was performed with an elder people chosen randomly from the group, in order to show how the Intelligent Pillbox should be used in a time of 5 minutes. After that, there was a time to receive questions from the study group about doubts of the functionality, alarms and alerts that the device has. In total, the final users (elderly patients) have had interactions with the device and its features for a time of 20 minutes, there was only one device to evaluate, so the interaction wasn´t possible with all people evaluated and wasn´t very intense, however, demonstration was carried out so that could see the operation and integral benefit.

After that, in order to carry out the surveys, each group filled out questionnaires to get correct responses and answer doubts about questions with the study group when necessary. This process was performed with the support of the developers and therapists of the groups of elderly people who assist to UAM and CAAM.

Figure No. 4 Empirical Validations of Intelligent Pillbox with elderly people in UAM and CAAM

6. Evaluation of the Intelligent Pillbox

The obtained results about perceived ease of use, perceived usefulness and intention to use in the future of the Intelligent Pillbox are presented in Figure 5 as box diagrams. These diagrams show that in all cases the measured variables are greater than the neutral variable, which has been stated in 3.

The anomalous data has been removed in all cases (see Figure 5). It has been concluded that the anomalous data is formed by surveys of patients with technological illiteracy or with difficulties to fully understand the device linked to the technology, these outliers correspond to participants 3, 26, 33, 35, 37. Once these outliers have been removed from the total data,

the results of the Shapiro-Wilk test, which are presented on Table 3, allow us to give answers about the hypotheses stated.

As it is shown in Table 3, the lowest value of PEOU is 3.2 and the maximum 5, it shows that the Intelligent Pillbox was perceived by the participants as easy to use in respect to the neutral variable. The mean was stablished in 4.405 and this perception variable shows a normal distribution ($p<0.01$).

Figure No. 5 Box Diagram of PEOU, PU and ITU

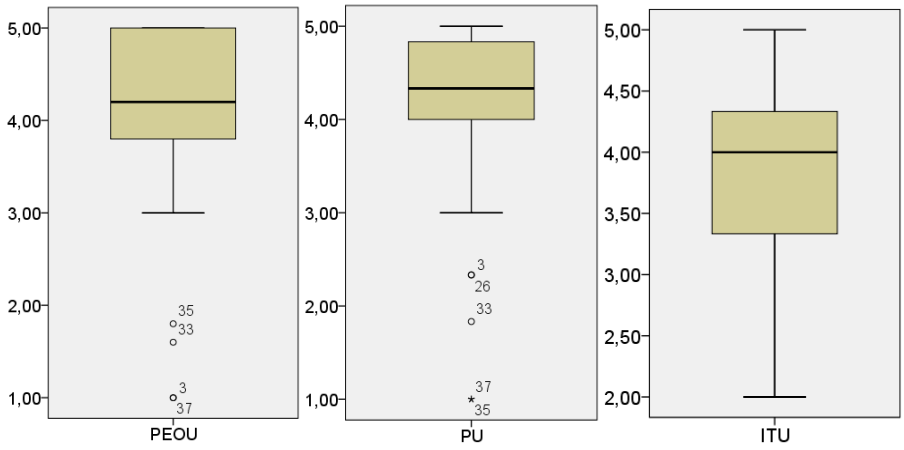


Table 3. Shapiro-Wilk test to Construction Variables of TAM.

Var	*Min*	*Max*	*Mean*	*Standard Dev.*	*Standard Error*	*Shapiro-Wilk test value-p*
PEOU	3.2	5	4.405	0.531	0.0839	0.001
PU	3	5	4.474	0.495	0.0783	0.001
ITU	2	5	3.958	0.696	0.1101	0.057

Then, in respect to the PU variable it is shown that the minimal value is 3 and the maximum value 5, with a mean of 4.47. It demonstrates that the users perceived the Intelligent Pillbox as useful. The results related to PU show a normal distribution as it can be demonstrated by using the Shapiro-Wilk test ($p<0.05$). Finally, the variable Intention to Use does not have a normal distribution ($p>0.05$), however the results shows a mean of 3.958, in citing an Intention to Use in the Future. Thus, the null hypotheses have been rejected.

Table 4. Causal Relations between PEOU and ITU

Reg. Element	*Coef (b)*	*Std. E.*	*Std. Coef.*	*t*	*Sig (p)*	*R*	*R^2*
Constant	3.127	0.934		3.347	0.002		
PEOU	0.189	0.211	0.144	0.896	0.376	0.144	0.021

As it was stated in the first open question, the main concern of the user is related to the size of the device. However, as this device has been presented as a prototype, it is planned to build final designs with an improved design that allows elderly people easier operation and transportation of the pillbox. Moreover, the second open question shows that users agree that this device can be a good tool towards a proper medication scheme. Besides, it can be useful to reminder complex medical schemes. Consequently, the system informs the caregivers or doctors the adherence and discipline in respect to the medication schedule. Therefore, health can be improved as a result of its use.

As the results show, there is not a significant variation between the PEOU and ITU in the future $p>0.05$ (i.e., 0.376), therefore it is possible to conclude that the intention to use this device in the future is not driven by the perceived ease of use. R^2 shows that the PEOU

variable can explain only a 2.1% of the variance of ITU. These results do not allow one to reject the $H4_0$, so it is thus determined that the use of this tool is not determined by the PEOU.

These results show that there is not a significant variation between the PU and ITU in the future $p>0.05$ (i.e., 0.914), therefore it is possible to conclude that the intention to use in the future of the device is not driven by the perceived usefulness. R^2 shows that the PEOU variable cannot explain the variance of ITU. These results do not allow one to reject the $H5_0$, so it is thus determined that the use of this tool is not determined by the PU.

Table 5. Causal Relations between PU and ITU

Reg. Element	*Coef (b)*	*Std. E.*	*Std. Coef.*	*t*	*Sig (p)*	*R*	*R^2*
Constant	3.848	1.026		3.750	0.001		
PU	0.025	0.228	0.018	0.108	0.914	0.18	0

As consequences of the hypotheses $H4_0$ and $H5_0$ it can be concluded that elderly people in a lot of cases need better knowledge of the tool and to understand their utility in depth, in order to better utilize these technological solutions. In spite of the good perceptions and clear intentions to use these solutions in the future (see $H3_0$) with respect to de device, they need greater incorporation with technology. These assumptions can be seen as logical, since the elderly are not digital natives. Therefore, the plan is to help them using different technological solutions by means of training and elementary ways to introduce them to the digital world.

In order to control the risk of variation due to individual differences being larger than those due to treatment, considered as a possible risk of the conclusion validity; it is important to note that the selection of subjects was selected from a homogeneous group. Moreover, the quasi-experiment implementation was taking into account a previous training and use of the device that provided to the participants a clear idea about the use of the Intelligent Pillbox. Moreover, to eliminate the construct validity risks, the reliability of the questionnaires has been analyzed by means of the Cronbach's analysis test. This analysis result was greater than the minimum acceptance threshold a=0.70. In order to mitigate additional risks, users had been informed about the benefits of the tool. However, it could be improved by means of the gradual overcoming of fear by the elderly to these new technologies.

Finally, as depicted in Table 2, questionnaires included two open questions in order to expand perception of final user about device and possible improvements in the pillbox. Between suggested changes can be mentioned: smaller device, make it portable, include a noisy alarm, indicate pill name in some cases to avoid mistakes and make intelligent pillbox's app friendly to final user.

7. Conclusions and Further Work

In this paper, the user perceptions of an electronic device The Intelligent Pillbox, have been evaluated. It has been created to remind elderly patients to take their medications. A prototype of this device has been proposed in order to show the functionality associated with the connectivity and facilities that this solution presents. Further, it has considered necessary evaluating this solution from the user perspective in order to improve it. Results show a good acceptance of this device, and elderly people agree that with it, they could improve the adherence to the medication prescribed. Therefore, forty five participants were selected in order to empirically evaluate the proposed solution, obtaining good results about the user perceptions of this device.

Thus, the no rejection of $H4_0$ and $H5_0$ provides us clear insight about certain fears that elderly people could have with respect to new solutions; however, with their greater involvement with technology, these fears can be overcome. Finally, it is important to take into account that the elderly play an important role in society. They are a priority group of healthcare. Therefore, it is necessary to create new devices by using emerging technologies [8]. Nevertheless, it is important to take into account recommendations for; having a device

with the same functionality in a smaller size; making it more portable; improving the alerting systems with nosier alarms; and improving the usability and accessibility.

Further work is planned to improve this device by adding a software platform connected by Wi-Fi, in order to configure the device from any location. Moreover, it is important to plan training sessions with the elderly that will help them get involved with the devices, applications and tools, in order to use new approaches related with these technologies to improve their lives (e.g., health, relationships, ludic activities, learning) and their integration with new generations.

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References

[1] P. E. R. John H. Brown, Lusignan, "United States Patent [19]," 1986.

[2] J. Lundell *et al.*, "Continuous activity monitoring and intelligent contextual prompting to improve medication adherence," *Annu. Int. Conf. IEEE Eng. Med. Biol. - Proc.*, pp. 6286–6289, 2007.

[3] e-pill medication Reminders, "E-pill Medication Reminders." [Online]. Available: www.epill.com.

[4] e-pill medication Reminders, "Automatic Pill Dispenser Medication Organizer e-pill med-time." [Online]. Available: http://www.epill.com/medtime.html.

[5] D. C. Park, R. W. Morrell, D. Frieske, and D. Kincaid, "Medication adherence behaviors in older adults: effects of external cognitive supports.," *Psychol. Aging*, vol. 7, no. 2, pp. 252–256, 1992.

[6] P. Casanova-Sotolongo, P. Casanova-Carrillo, and C. Casanova-Carrillo, "Deterioro cognitivo en la tercera edad," *Rev. Cuba. Med. Gen. Integr.*, vol. 20, no. 5–6, 2004.

[7] World Health Organization, "How age may afect drug action. Drugs for the Elderly." 1997.

[8] J. M. Parra, W. Valdez, A. Guevara, P. Cedillo, and J. Ortíz-Segarra, "Intelligent pillbox: Automatic and programmable Assistive Technology device," *13th IASTED International Conference on Biomedical Engineering (BioMed)*. pp. 74–81, 2017.

[9] F. Davis, "A technology acceptance model for empirically testing new end-user information systems : theory and results." p. 291, 1989.

[10] P. J. Hu, P. Y. K. Chau, O. R. Liu Sheng, and K. Y. Tam, "Examining the Technology Acceptance Model Using Physician Acceptance of Telemedicine Technology.," *J. Manag. Inf. Syst.*, vol. 16, no. 2, pp. 91–112, 1999.

[11] J. Hartwick and H. Barki, "Research Report — Hypothesis Testing and Hypothesis Generating Research : An Example from the User Participation Literature," *Inf. Syst. Res.*, vol. 5, no. 4, pp. 446–449, 1994.

[12] H. M. Selim, "An empirical investigation of student acceptance of course websites," *Comput. Educ.*, vol. 40, no. 4, pp. 343–360, 2003.

[13] R. van Solingen, V. Basili, G. Caldiera, and H. D. Rombach, "Goal Question Metric (GQM) Approach," in *Encyclopedia of Software Engineering*, John Wiley & Sons, Inc., 2002.

[14] R. W. Grant, N. G. Devita, D. E. Singer, and J. B. Meigs, "Polypharmacy and Medication Adherence in Patients With Type 2," *Diabetes Care*, vol. 26, no. 5, pp. 1408–1412, 2003.

[15] A. F. Yap, T. Thirumoorthy, and Y. H. Kwan, "Medication adherence in the elderly," *J. Clin. Gerontol. Geriatr.*, vol. 7, no. 2, pp. 64–67, 2016.

[16] L. G. Park, J. Howie-Esquivel, M. L. Chung, and K. Dracup, "A text messaging

intervention to promote medication adherence for patients with coronary heart disease: A randomized controlled trial," *Patient Educ. Couns.*, vol. 94, no. 2, pp. 261–268, 2014.

[17] M. Morales, "Estudio sobre la utilitdad del pastillero para mejorar el cumplimiento terapéutico," *Atención Primaria Journal*, vol. 41, no. 4, pp. 185–91, 2009.

[18] T. L. Hayes, J. M. Hunt, A. Adami, and J. A. Kaye, "An electronic pillbox for continuous monitoring of medication adherence," *Annu. Int. Conf. IEEE Eng. Med. Biol. - Proc.*, pp. 6400–6403, 2006.