

## **A Method to Build Serious Games for Older Adults ADE2: Evaluation of User Perceptions and Threats of Validity**

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### **Abstract**

Over the years, people decrease their ability to remember certain events, which is more evident in older adults. Therefore, cognitive health professionals use tools and methods to train and assess attention and memory, among those solutions are found serious games. These games are intended to teach, while the player has fun. These games' demands high Human-Computer Interaction (HCI) characteristics which are not formally included during their development. In other contributions, it has been presented a first approach of a method to build serious games named ADE2. In that studies we established as further work the need of perform the empirical evaluation of the solution. Therefore, this paper presents an experimental process in which the ADE2 method has been evaluated by 22 software engineers, who evaluated it by using the Method Evaluation Model (MEM). The results show that the ADE2 method can be successfully adopted by the software engineering community and the actions performed by following each step of the method can be reached effectively and efficiently.

**Keywords:** older adults, serious games, human-computer interaction, evaluation

### **1. Introduction**

One of the objectives of Human Computer Interaction (HCI) is to improve the individual's experience with technological software solutions interfaces [3]. There are multiple technological solutions where the different age groups (children, youth, older adults, among others) have not been considered [14]; these solutions lack standards and usability guidelines [3, 4]. Similarly, most studies are focused on the young population, but studies are required to improve new technologies with older adults [8].

Specifically, older adults, over the years, begin to present problems in their daily lives, such as remembering, learning, concentrating, and making decisions on their own [4],[8],[20]. This situation requires the intervention of professionals in cognitive health [8].

Then, memory training techniques are applied, improving attention deficit problems and cognitive problems in the older people [3],[13].

On the other hand, video games are products with the highest commercial rate worldwide. One of the reasons is because, video games implement new interaction methods and multiplayer [4],[14]. Here, serious games are also included, because they are applied in education, memory training, and improving older adults' cognitive abilities, among others [4],[8]. Serious games are cognitive solutions, they are currently preferred because allow the integration of assistance tools, are less expensive, and more accessible [4]; unfortunately, many of those games are not adapted to the needs, characteristics, and specific preferences of older adults [4].

Moreover, Tost et al., [20] designed and implemented a game following the agile methodology, but this study does not apply standards and methodologies focused on older adults. Hence, there is a need to create serious games for older adults based on various techniques, to improve interaction and facilitate development. Also, Santos et al., [19] have proposed serious games using sensors to perform physical rehabilitation and prevent falls. Also, several studies [10],[13],[17] have described serious game development methodologies, and their validation has been performed with older adults. However, it is also necessary to evaluate the method through the designers and developers of software, who are the ones who build the serious games. Previously, in [6] a case study with older adults was presented; it used a serious games, which was created following the ADE2 method. To complement the evaluation, it is necessary to evaluate the method with software engineers to measure their perceptions. Therefore, this study performs an empirical evaluation of ADE2 method by using the Method Evaluation Model (MEM), which is used to evaluate methods through the constructs of perceived efficiency and current use [16].

This paper is structured as follows: Section 2 describes the analysis of related works; Section 3 briefly describes the ADE2 method. In Section 4, the method's evaluation is presented using the MEM method and the process for experiments proposed by Wohlin [21]. Section 5 presents the analysis of the threats that could put the validation experiment of the ADE2 method at risk. Finally, Section 6 presents the conclusions and future work.

## 2. Related Work

Many authors have discussed about the perceptions that an older adult end-user has about serious games. Some of them, which combine the players' physical and mental abilities have been implemented [10],[13],[17] In this context, Lin et al., [13] explore the user experience of software used in a casual and social environments. With a game, called GuessMyCaption, it was possible to identify that the use of natural interfaces and family memories or movements facilitate the adoption of serious games in older adults.

Similarly, Cornejo et al., [10] focus on stimulating older adults' physical and cognitive functions by proposing a game that involves hand-eye coordination. For this, the authors created a serious game with a modular design, for which three scenarios were developed. In this game, data were collected and subsequently analyzed, indicating that serious games are very attractive for older adults and are something that can be applied in their daily life.

Pesántez et al., [17] focus on a model that includes and evaluates accessibility characteristics of serious games built using model driven approaches. Said study deals with older adults who have difficulties in mitigating age-related cognitive problems. For this, they created a method called Evaluation Method of Accessibility for Serious Games (EMASG). After the evaluation, it can be observed that to develop a serious game that has accessibility, it is necessary to start with the interest of the end-user from the beginning, also use accessibility criteria for each function.

These aforementioned contributions present the reactions of older adults when they use serious game built with an specific methodology, and how friendly they are when these games are used by end-users. However, none of them present how challenging it is for developers, engineers, and experts in the domain to create serious games efficient, which in turn meet the required accessibility criteria.

In a previous study, was presented the creation of a methodology (ADE2), alongside a brief explanation of its use through a study case with the participation of older adults. It consisted on the creation of serious games focused on attention and memory for the elderly people. Therefore, this article aims to evaluate the effectiveness and efficiency of methodology ADE2 when it is applied by software engineers, to create serious games focused on supporting and training the older adults' attention and memory.

### 3. ADE2: A Brief Review About the Method

Serious games are solutions that aim to amuse or entertain participants through mental or physical tests [7]. This is why these games can involve different types of participants (e.g. children, young people, elderly people). Then, to provide games that provide the best experience for an older adult, a method to create serious games for older adults (ADE2) was proposed. To clarify the main activities of ADE2, this section provides a brief explanation of each activity. ADE2 presents the necessary steps to create serious games to reinforce the areas of attention and memory in an older adult [6].

Therefore, the ADE2 method is divided into six main activities (See Fig 1). Each activity includes its input and output artifacts and guidelines. The first activity is “Analyzing the Situation”, this activity contains geriatric protocols and standards, which are used during software requirements elicitation. As result of this activity, the Domain Expert and Requirements Engineer, create the Domain Analysis Document, using the Domain specifications Document. The second activity “Analyzing the Software Requirements”, collects all the requirements to be included in the serious game. Here, the Video Games Designer, Health Personnel and HCI Expert participate. Then, there is the “Designing” activity, it considers accessibility criteria from the W3C and HCI design principles oriented to older adults [5],[18] to provide a game that is easy to understand and to use.

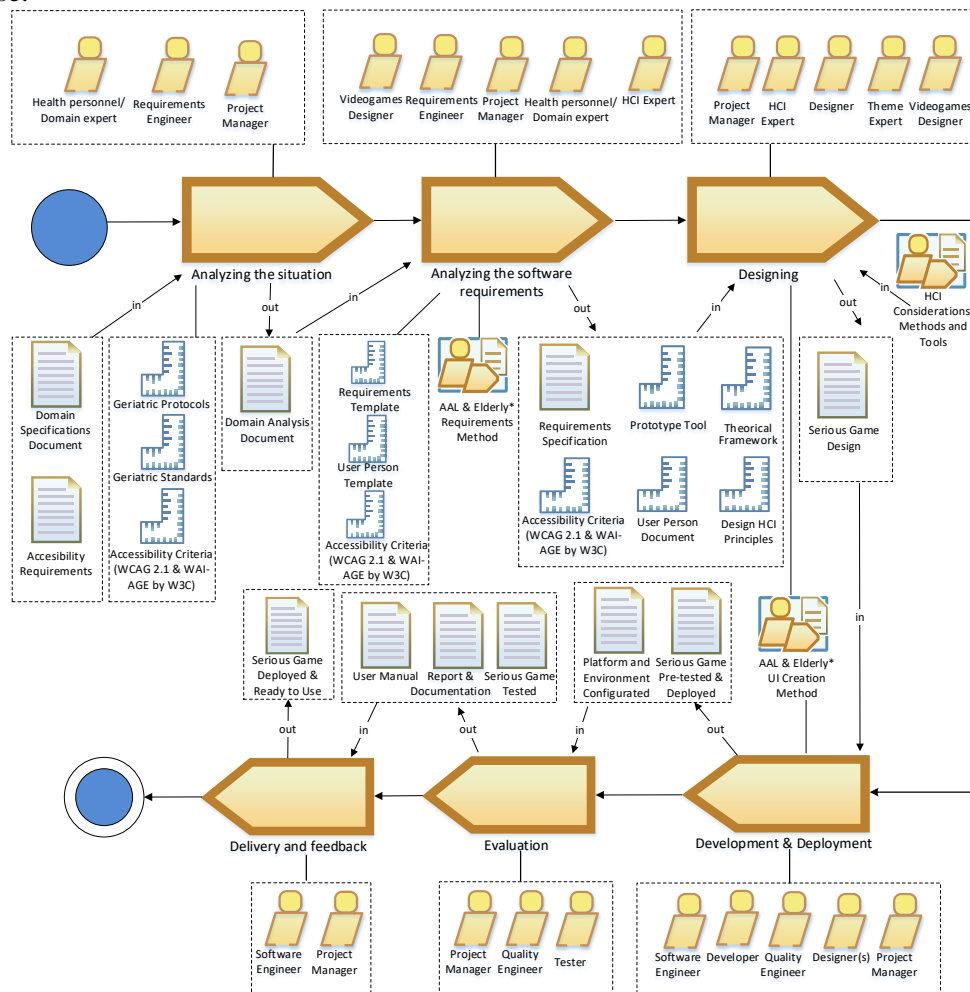


Fig 1. ADE2 Method (\*\*AAL & Elderly: Ambient Assisted Living and Elderly)

Moreover, the “*Development & Deployment*” activity consists of creating the user interface focused on older adults, using the AAL &Elderly\* UI creation method and the serious game design. Then, the Quality Engineer and Developer implement the game. The other activity is “*Evaluation*”, here, the Tester and the Quality Engineer try the serious game, then inform in the Report & Documentation, the changes and improvements in the software. The final result is the user manual for the game. Finally, in the “*Delivery and Feedback*” activity, the Software Engineer and the Project Manager approve releasing the cognitive solution for use with older adults.

## 4. ADE2 Method Evaluation

### 4.1. Evaluation Method

In Cedillo et al., [6] a prototype was presented and evaluated with older adults. Then, to evaluate the acceptance and the performance in the method ADE2, the Method Evaluation Model (MEM) proposed by Moody [16] was applied. The main focus of the MEM is the evaluation of the effectiveness of the created method; therefore, it is necessary to take into consideration the following:

- Measure the effort required to apply the method and its quality in terms of the results obtained.
- The current efficiency, which is the user's effort to understand and apply the method, it can be assessed on the situation in which the MEM is applied.
- The effectiveness, which is the quality of the method, in many cases can be a measure that is determined by the user's ability to perform a certain activity and taking into account its success or failure.

The MEM constructs are based on the Technology Acceptance Model (TAM) proposed by Davis [11]. TAM is a widely used theoretical model, it allows measurement of perceptions to determine the intention to use new creative technology in the future. The constructs to measure the performance and the perceptions are presented in Fig 2.

- Perceived Ease of Use (PEOU): Degree to which a user believes that using a system will relieve stress.
- Perceived Utility (PU): Degree to which a user believes that using a system will highlight the work.
- Intent to Use (ITU): The extent to which the user is interested in using a particular system.

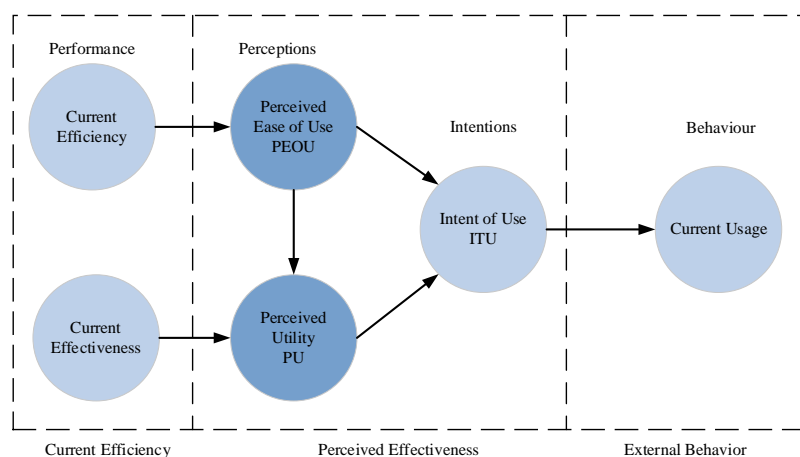


Fig 2. Method Evaluation Model (MEM). [16]

## 5. ADE2 Evaluation

This section details how the MEM was applied [16], the criteria, variables and questions which were considered during the execution and analysis of the experiment. To apply the

MEM [16], it is necessary to specify the user requirements, depending on the problem's domain to resolved; in this case; the requirements are oriented to the elderly. Then, evaluations of the proposed method aimed at designing user interfaces will be carried out. The following objectives arise i) Design application interfaces that include accessibility criteria for older adults, ii) Create easy, intuitive and user-friendly user interfaces, iii) Design an interface to meet the user's functional requirements, iv) Create an interface that provides the best user experience to the older people.

The method proposed by Wohlin et al. [21] has been applied to perform the quasi-experiment; this method presents the following phases: i) Definition of the scope, ii) Planning of the quasi-experiment, iii) Operation, iv) Analysis and interpretation, and v) Presentation and reporting [16]. These phases are described below:

### 5.1. Scope Definition

Authors of [2] mention the Goal-Question Metric (GQM) to define a project's goal; this approach was applied to perform the quasi-experiment. Analysis is presented on Table 1.

**Table 1.** Scope definition with GQM.

GQM variable	Response
Evaluate	ADE2 Method
With the purpose of	Evaluate the method concerning perceived efficacy, intended future use, and perceived ease of use
From the viewpoint of	Software Engineer
In the context of	A group of professionals in the technical area (Computer Science and related careers)

Then, the following research questions were defined; RQ1: Is the ADE2 method perceived as easy to use and useful?? If so, are users' perceptions the result of their performance when using the method to develop serious games? and RQ2: Is there an intention to use the ADE2 method in the future? If so, are those usage intentions the result of the participants' perceptions?

Finally, to answer question RQ1, the hypotheses H1, H2, H4, and, H5 have been defined, and to answer RQ2, the hypotheses have been defined: H3, H6, H7, and H8; they are described below:

- H1<sub>0</sub>: The design phase of the ADE2 method is perceived as difficult to use  $\neg$ H1<sub>1</sub>.
- H2<sub>0</sub>: The design phase of the ADE2 method is not perceived as useful  $\neg$ H2<sub>0</sub>
- H3<sub>0</sub>: There is no intention to use the design phase of the ADE2 method in the future.  $\neg$ H3<sub>0</sub>
- H4<sub>0</sub>: Perceived ease of use cannot be determined by efficiency. Efficiency is based on current efficiency performance and perceived ease of use is based on perception.  $\neg$ H4<sub>0</sub>
- H5<sub>0</sub>: The perception of utility is not determined by effectiveness. This hypothesis is given since, the effectiveness is based on the performance and the perceived utility is based on the perception of the effectiveness.  $\neg$ H5<sub>0</sub>
- H6<sub>0</sub>: Perceived utility is not determined by perceived ease of use. The perceived ease of use is found to have no influence on the perceived usefulness. This hypothesis is taken from the TAM.  $\neg$ H6<sub>0</sub>
- H7<sub>0</sub>: Intent to use is not determined by perceived ease of use. The perceived ease of use influences the intention to use, described in the TAM.  $\neg$ H7<sub>0</sub>
- H8<sub>0</sub>: Intent to use is not determined by perceived utility. The perceived utility has an influence on the intention to use, described by TAM.  $\neg$ H8<sub>0</sub>

Based on the aforementioned, Table 2 presents a questionnaire of 14 questions, which were used to measure the variables. The questionnaire items were formulated using a 5-point Likert scale [12], with the opposite statement question format. Several items within the same construct group were randomized to avoid systemic response bias. The PEOU is measured through the use of five questions in the survey, the PU is measured with six questions, and the ITU is measured with three questions in the survey.

**Table 2.** Questions to assess user perceptions.

Question	Statement Positive (5 points)
PEOU1	The design phase of the ADE2 methodology is simple and easy to follow.
PEOU2	In general, the design phase of the methodology is easy to understand.
PEOU3	The steps of the design phase of the methodology are clear and easy to understand.
PEOU4	The design phase of the methodology is easy to learn.
PEOU5	I think it would be easy to master the design phase of the ADE2 methodology.
PU1	I believe that the design phase of the ADE2 methodology could reduce the time and effort required.
PU2	I consider that the design phase of the methodology is useful.
PU3	I consider that the design phase is useful to improve the design of interfaces that relate to older adults.
PU4	I think that the design phase of the methodology is expressive enough to define interfaces oriented to older adults.
PU5	The use of this design phase could improve the performance of creating technological solutions focused on older adults.
PU6	In general, I think that this design phase of ADE2 can be used to help develop technological applications focused on older adults.
ITU1	If you need to design a technology application focused on older adults, would you consider the design phase of the ADE2 methodology.
ITU2	If necessary, I would use the ADE2 design phase in the future.
ITU3	I would recommend using the design phase of ADE2.

## 5.2. Planning of the quasi-experiment

A problem is described for both the demonstration session and the experimentation session to evaluate the ADE2 method. For this, the following tasks must be carried out:

Task 1: Obtain the requirements based on the problem; this means that software engineers are given a list of requirements included or excluded in the experimentation exercise.

Task 2: Identify the tool that will be used to prototype the application. In this task, software engineers must select characteristics that a prototyping tool must meet to satisfy the proposed problem.

Task 3: Select the accessibility criteria; in this task, the accessibility criteria that are appropriate for the user application are chosen. These accessibility criteria are proposed by WCAG 2.1 & WAI-AGE by W3C in [1].

Task 4: Make a prototype where the selected tool is used, and the criteria seen in task 3 are applied. Also, the accessibility criteria seen in task 1 must be met.

## 5.3. Operation

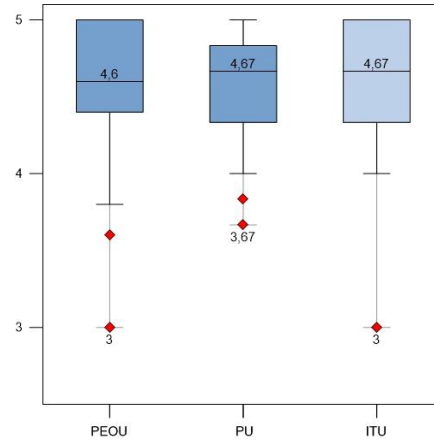
The training was performed online, using the Zoom platform to experiment. Twenty-two engineers (eight women and fourteen men) corresponding to technical areas participated, selected according to the skills and knowledge they possess to evaluate the ADE2 method. To experiment, four-points were defined:

- Define a web page: a simple web page was created so that the parameters that must be met in evaluating the methodology can be observed, with a training, experiment, survey, and video tab. The web page is found at the following URL: <https://sites.google.com/ucuenca.edu.ec/evaluacion-ade2/p%C3%A1gina-principal>.
- Training: documents related to the application guide, the phases of the methodology, what is accomplished in each one of them, and how the flow is going.
- Experiment: contains all documents necessary to experiment.
- Survey: is a questionnaire that the participants must answer after completing the exercise. The survey response matrix will be used to measure the Perceived Ease (PEOU), the Perceived Utility (PU), and the Intent to Use (ITU).

**5.4. Analysis and interpretation**

*Analysis of user perceptions*

The analysis was performed with box plots and descriptive statistics. Fig 3. shows the box plot; the values obtained for the PEOU, PU, and ITU variables have a value greater than the neutral value (3) of the Likert scale.



**Fig 3.** Box plot for perception variables PEOU, PU and ITU.

The Shapiro-Wilk test was performed to determine if the data has a normal distribution, then a test was selected to accept or reject the hypothesis H1, H2, and H3. It was obtained that the variables PEOU, PU, and ITU do not have a normal distribution with  $p < 0.05$  (see Table 3); here, the Wilcoxon test was applied. The results allow knowing that the hypothesis H1<sub>0</sub>, H2<sub>0</sub>, and H3<sub>0</sub> were rejected. Thus, the alternative hypothesis H1<sub>1</sub>, H2<sub>1</sub>, and H3<sub>1</sub> were accepted.

**Table 3.** Shapiro-Wilk test for the perception-based variables

Var	Min	Max	Media	Std. E.	Shapiro-Wilk test p-Value
PEOU	3,6	5	4,7	0,42	0,000
PU	3,66	5	4,61	0,36	0,017
ITU	3,66	5	4,73	0,37	0,000

*Performance analysis*

User performance data is obtained from the tasks performed by the participants. Equation 1 shows the calculation of the efficiency, and Equation 2 shows the calculation of the effectiveness in the design phase of the ADE2 method. The results obtained are shown in Table 4. On the one hand, the efficiency has a mean value of 20.71 minutes; the minimum value is 16; the maximum value is 29. On the other hand, the effectiveness has a mean value of 0.9 which means that the design phase provides great effectiveness (90%) because the answers to the proposed solutions were correct.

$$efficiency = \sum_{i=1}^n Time\ per\ activity \tag{1}$$

$$effectiveness = \sum_{i=1}^n \frac{Number\ of\ tasks\ completed\ successfull}{Total\ number\ of\ tasks} \tag{2}$$

**Table 4.** Performance Analysis

Variable	Min	Max	Media	Std. Dev.
Efficiency	16	29	20,71	3,49
Effectivity	0,59	1	0,9	0,10

*Analysis of causal relationships*

MEM's structure has been analyzed, that is, the causal relationships between perception variables and performance variables. The regression analysis was performed, and to determine

the level of significance of the regression model, the levels suggested in [15] were applied. Table 5 shows the results obtained, and the analysis for each causal relationship is presented below:

- In causal relationship between Efficiency and PEOU, the regression model is not significant, with  $p > 0.1$ .  $R^2$  represents 0.02% of the variance in PEOU. As a result, the current efficiency of the participants does not influence their perceptions of ease of use. This allows corroborating which hypothesis H40 is accepted, that is to say, Efficiency does not determine the Perceived Ease of Use.
- In causal relationship between Effectivity and PU, the regression model is not significant, with  $p > 0.1$ .  $R^2$  represents 0% of the variance in PEOU. As a result, the current effectiveness of the participants do not influence their perceptions of perceived utility. This allows corroborating that hypothesis H5<sub>0</sub> is accepted, that is, effectiveness does not determine utility.
- In causal relationship between PEOU and PU, the regression model was found to be of medium significance with  $p < 0.05$ .  $R^2$  shows that the PEOU variable is capable of explaining 30% of the variance in PU. As a result, the number of perceptions regarding PU is not determined by PEOU. This makes it possible to reject hypothesis H6<sub>0</sub>, that is, PEOU determines PU.
- In causal relationship between ITU and PU, the regression model is not significant, with  $p > 0.1$ . The  $R^2$  shows that the PU variable is capable of explaining 13% of the variance in ITU. As a result, the number of perceptions regarding ITU is determined by PU. This allows the H7<sub>0</sub> hypothesis to be accepted, that is, the intention to use is not determined by the perceived ease of use.
- In causal relationship between ITU and PEOU, the regression model was found to be of low significance with  $p < 0.1$ . The  $R^2$  shows that the PEOU variable is capable of explaining 15% of the variance in ITU. As a result, some of the perceptions regarding ITU is determined by PEOU. This allows the H8<sub>0</sub> hypothesis to be rejected, that is, the intention to use is determined by the perceived utility.

**Table 5.** Simple regression casual relationships

Reg. Element	Coef(b)	Std. E.	Std. Coef	t	Sig(p)	R	R <sup>2</sup>
Simple regression between Efficiency and PEOU							
Constant	4,601	0,582	----	7,909	0	----	-----
Efficiency	0,005	0,028	0,042	0,182	0,858	0,042	0,002
Simple regression between Effectivity and PU							
Constant	4,67	0,756	----	6,169	0	----	-----
Effectivity	-0,05	0,832	-0,015	-0,063	0,95	0,015	0
Simple regression between PEOU and PU							
Constant	2	0,782	----	3,033	0,007	----	-----
PEOU	0	0,166	0,552	2,884	0,01	0,552	0,304
Simple regression between ITU and PU							
Constant	2,989	1,012	----	2,954	0,008	----	-----
PU	0,377	0,218	0,368	1,725	0,101	0,368	0,135
Simple regression between ITU and PEOU							
Constant	3,069	0,881	----	3,484	0,002	----	-----
PEOU	0,353	0,187	0,398	1,893	0,074	0,398	0,159

## 5.5. Presentation and report

Within the results report and based on results shown in Table 6, each research question will be analyzed:

RQ1: Is the ADE2 method perceived as easy to use and useful? If so, are users' perceptions the result of their performance when using the method to develop serious games? Here, most participants perceived the design phase of the method ADE2 as easy to

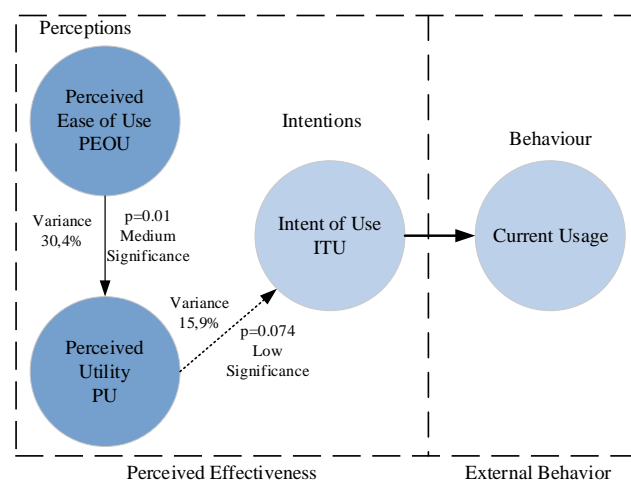


use and useful. This is because hypotheses  $H1_0$  and  $H2_0$  have been rejected and their alternatives  $H1_1$  and  $H2_1$  have been accepted. Besides, by accepting hypothesis  $H4_0$  and  $H5_0$ , it was known that ease of use is not determined by efficiency, and utility is not determined by effectiveness either. On the one hand, most participants completed the tasks correctly; this is evident because the effectiveness is 90%. However, several participants had problems when applying accessibility criteria for the prototype, and on the other hand, the efficiency was altered because some participants had internet connection problems. The average time to complete the tasks was 16 minutes.

**Table 6.** Evaluation Summary

Hypothesis	Range	Significance	Action	Results
$H1_0$	----	----	Rejected	ADE2 is easy to use
$H2_0$	----	----	Rejected	ADE2 is perceived as useful
$H3_0$	----	----	Rejected	There is an intention to use ADE2
$H4_0$	$p > 0.1$	not significant	Accepted	PEOU is not determinate by efficiency
$H5_0$	$p > 0.1$	not significant	Accepted	PU is not determinate by effectivity
$H6_0$	$p < 0.05$	medium significance	Rejected	PEOU is determine by PU
$H7_0$	$p > 0.1$	not significant	Accepted	ITU is not determine by PEOU
$H8_0$	$p < 0.1$	low significance	Rejected	ITU is determine by PU

Finally, to RQ2: Is there an intention to use the ADE2 method in the future? If so, are those usage intentions the result of the participants' perceptions? The hypothesis  $H3_0$  was rejected, and with this, it was determined that the participants intend to use it in the future. Then, hypothesis  $H6_0$  was rejected, this means that the perceived utility is determined by the perceived ease of use with a 30.4% variance; hypothesis  $H7_0$  was accepted, this means that the perceived ease of use does not determine the intention of use; hypothesis  $H8_0$  was rejected with a 15.9% variance, and this means that the perceived utility determines the intention to use. These data are represented in Fig 4.



**Fig 4.** Conclusion of the application of MEM to the ADE2 method.

## 6. Threats of Validity

This section presents the main problems that can jeopardize the validity of the experiment. Cook and Campell [9] consider four types of validity: conclusion, internal, construct and external:

### 6.1. Internal Validity

The threat to internal validity was influenced by the quality of the internet used by the participants, in addition to the use of virtual platforms. However, the participants present in the quasi-experiment decided to participate voluntarily in a virtual way, for which, a letter with the invitation was sent via email and the entire training process was recorded. Also, a web page was prepared to carry out the quasi-experiment, a presentation video of the ADE2 method to avoid bias.

## 6.2. External Validity

External validity refers to the results generated in different contexts, and its main threat was the current COVID-19 pandemic; the quasi-experiment cannot be applied in person. A training session and a pilot test were conducted to avoid internet connection problems to reduce this threat. This allowed the participants to perform the assessment tasks with ease.

## 6.3. Validity of the Construct

The main threat to the validity of the construct is the reliability of the questionnaire. To increase reliability, the Cronbach's alpha test of questions related to each subjective variable was performed. The minimum accepted threshold being  $\alpha = 0.70$ , then, the following results were obtained for the PEOU variables  $\alpha = 0.76$ , in PU  $\alpha = 0.79$  and in ITU  $\alpha = 0.77$ . These values have been obtained by conducting a pilot study with 5 software engineers. It was determined that the questionnaire is reliable and can be applied to evaluate the ADE2 method.

## 6.4. Conclusion Validity

The sample size and selection are made up of 22 participants belonging to professionals in the technical area; this amount may reflect a problem of the validity of the conclusion. However, the results are very satisfactory since the participants managed to develop correctly the steps established in the quasi-experiment exercise. For future work, an experiment with differentiation has been proposed to validate the ADE2 Methodology with a larger sample.

## 7. Conclusions and Future Work

ADE2 is a method that allows to create serious games for older adults. This method contains phases, roles, guides, and artifacts that contribute to improving users' interaction with serious games. This paper presented the evaluation of software engineers of the ADE2 method. Here, the method evaluation model (MEM) was applied, evaluating user perceptions based on their performance. The method is easy to use, useful, and intended by engineers to use in the future to build serious games, and threats that may put the quasi-experiment at risk have been analyzed.

As future work, it is sought to extend the experiment to different groups of software engineers with a bigger sample, with it will present a family of experiments to corroborate the hypotheses tested in this work and to provide more accurate results. It is also intended to create other serious games by applying ADE2 in the research group. This contributes to the cognitive improvement of older adults who live at home and in care and assistance centers.

## Acknowledgment

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