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Technique for representing requirements using personas: a controlled experiment

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Abstract: Understanding the users' needs is important for designing an application that provides a good usage experience. One can use design thinking (DT) to help identify those needs. Persona is a technique used in DT to support the requirements elicitation by describing user profiles. Nevertheless, the persona descriptions created using a traditional template may include many details about the users that are not relevant to the application design. To overcome this limitation, the authors proposed the PATHY technique to guide software engineers in creating and describing more useful personas, i.e. personas with information that is more relevant to the application design. They conducted an experiment to compare PATHY to another persona-based technique which uses a traditional template and also supports the representation of the application's requirements. In this study, they assessed which of the two techniques helps to generate descriptions of personas that are more focused on potential requirements to consider in the design of the application. In addition, they analysed the efficiency of the techniques and the participants' perception of use. The results showed that PATHY generated more relevant characteristics for the application design than the technique that follows the traditional description. The PATHY was also more efficient for creating personas.

1 Introduction

The software industry has become extremely competitive: there is a wide variety of applications in the same domain, competing with one another to better satisfy users [1]. In this context, understanding the users is an important factor for the design of applications that meet the stakeholders' needs and expectations [2]. One way to focus on the users during software development is by adopting the design thinking (DT) process [3]. The use of DT helps us to understand the users' needs through empathy. Empathy can be defined as to think as if we were in another person's shoes to understand their point of view [4] and needs. Empathising is important because it helps the software engineer to understand the needs of the users who will interact with the application [5]. One technique that we can use within the DT process to empathise with users is personas [6]. This technique helps the stakeholders to understand and create empathy with users' profile (personas), make decisions, and identify requirements based on these personas' needs and expectations.

Persona is a technique that proved useful in requirements elicitations and design activities within software engineering [7]. However, while it is useful for identifying requirements, it is difficult to integrate the technique into the development process; this can hinder its use by the development team. The technique consists mainly of organising information about the user collected with elicitation requirements techniques. Based on this information, the development team understands the users' characteristics and defines specific descriptions of user groups. This technique keeps the development team's focus on the personas throughout the software development process [2]. Personas are usually based on extensive research with user groups, which sometimes require a long time [8]. However, sometimes the development team does not have either the time or the budget to perform user research [9]. Furthermore, the access to users may be limited [10], i.e. sometimes the development team may not have end users available to participate in the process. Therefore, the definition of characteristics and specific needs of the target users of an application during the creation of personas can be difficult due to the lack of access to end users. Another critical aspect when using the technique is that the created personas should be composed of attitudes (motivations, beliefs, wishes) and behaviours (e.g. searched information, accessed tools, performed tasks) [11]. Attitudes are important for creating empathy with the user, while behaviours are important for designers and developers to understand how the product will be used, informing what should be designed. In the context of this study, the characteristics that can inform the application design are called potential requirements. Nevertheless, many personas are created with more emphasis on attitudes and, as a result, their behaviours are described only superficially [11]. Consequently, the descriptions of personas can include a lot of information that may not help directly in the application design (e.g. hobbies, personas' pets) [9].

In our research, we have developed the PATHY technique to help software engineers create empathy and identify and represent relevant characteristics during an application design. The personas created with the technique are elaborated based on information collected using elicitation techniques (e.g. questionnaires, interviews), meetings with stakeholders or specific researches. The technique is based on a template composed of six fields. These fields consider the persona's attitudes (personal characteristics that help create empathy) and behaviours (characteristics that help think of potential application requirements). Each field has guiding questions that should be answered based on information collected from users, through available resources on the internet (for example, feedback from the app stores), or any other source of information about the users and their goals, needs, and preferences. The guiding questions aim to help obtain detailed information about a persona's behaviours that contribute directly to the application design.

We carried out an experiment to verify whether PATHY generates more and better potential requirements than the other techniques that use a more traditional template, which does not provide guiding questions. In our study, we compared PATHY with the technique proposed by Acuña *et al.* [12]. We chose their technique because it is quite similar to PATHY: it also aims to support requirements elicitation and representation, by providing a detailed template to use personas. The main difference is that, unlike PATHY, their approach does not use guiding questions. The

results of the experiment include a qualitative analysis of the participants' perception about the use of the techniques, a qualitative analysis of the created personas to identify the types of information generated using each technique, and a comparison between the efficiency of the techniques (PATHY and Acuña *et al.*'s).

The paper is organised as follows: Section 2 presents concepts related to DT and personas, and Section 3 presents the PATHY technique. Then, Section 4 describes the conducted study. Section 5 presents the study results and Section 6 discusses the threats to validity. Finally, Section 7 presents our conclusions and future work.

2 Background

This section describes the DT process, the concept of personas, and Acuña *et al.*'s technique for creating personas.

2.1 Design thinking

DT can be defined as a methodology that uses designers' perceptions and methods to combine: (a) users' needs, (b) technology feasibility, and (c) what a feasible business strategy can convert into customer value and market opportunity [5]. The DT process generates innovative products collaboratively. The main focus of DT is on how designers advance in the design process with a creative mind to generate solutions by discovering new opportunities [13].

One of the DT's most common processes [14] is composed of five phases: empathy, definition, ideation, prototyping, and testing [6]. In the empathy phase, we conduct in-depth studies to understand the users' needs. The goal of this phase is to perform early research about the problem that the application should solve and its possible users. Personas, interviews, and ethnography are examples of techniques used in this phase. After collecting information about the problem domain, the next phase is definition, in which the collected information is analysed and we make an initial definition of the problem. In this phase, we can use the user journey map technique. The next phase is ideation; in this stage, we generate solutions to the problem defined in the previous stage. Brainstorming techniques can be used in this phase. In the prototyping stage, we build prototypes that can be manipulated by users. Finally, in the testing phase, the users evaluate the prototypes [15]. In this phase, we can use usability and user experience evaluation techniques or feedback questionnaires.

As previously mentioned, one of the techniques that we can use in the DT process to help us know the users and their needs more deeply involves creating personas. This technique is generally used in the empathy phase. Personas can help the stakeholders empathise with the application's end users through profile descriptions that represent them.

2.2 Personas

A persona is a hypothetical archetype of a real user [5] that describes the user's goals, skills, and interests [16]. Personas are used to stimulate empathic thinking by developing an application and helping the development team to involve users indirectly in the creation of the system [6].

In a traditional template, personas are textual descriptions that include information about a person's attitudes (characteristics related to someone's personality) and behaviours, focusing on attitudes [7]. Among the benefits of using personas, Cooper [16] lists: (i) it helps the development team to understand the characteristics of a user group; (ii) it proposes solutions related to the main needs of the users; and (iii) It provides a human face as a way to bring the team closer to potential end users. However, personas are controversial [17]. Descriptions of personas generally contain a lot of information about personal details of the personas' lives, which become irrelevant to the application development [11]. It is necessary to achieve equilibrium between information about the persona's personal characteristics and the features that really help in the application design [11].

Several techniques to describe personas have been proposed. Acuña *et al.* [12] include new steps to adapt personas to the software development process. They present examples of using their technique to create personas of an application to sell flight tickets. Idoughi *et al.* [18] proposed a technique where elements of the persona help to design the application interface while the identified functionalities are extracted. They used this technique to design an e-maintenance system. Among the conclusions, they state that the main problem with the application of personas is the lack of a clear standard for describing the persona's information. Aoyama [19] proposed the Hanako method to integrate scenarios and personas. The method is goal driven and helps to extract requirements from a group of users. The efficacy of this method was evaluated through a case study, which showed that using the method helps in identifying requirements for an application. However, the authors cite that it is necessary to overcome conflicting requirements and to carry out studies using other application domains. Bhattarai *et al.* [20] proposed a technique where personas are created with stakeholders and may have users involved in creating personas or not. In addition, their technique involves creating an ecosystem of personas, also describing the relationship between the created profiles. Cleland-Huang *et al.* [21, 22] and Rahimi and Cleland-Huang [23] present a technique in which the created personas contain elements of system architecture. Their technique uses data mining to organise user data that is required for creating profiles. Khalayli *et al.* [24] describe a technique where personas are created integrated with scenarios. Scenarios are broken down into tasks and user profiles are constructed. Sim and Brouse [25] proposed a process where both personas and scenarios are created and from those, UML diagrams are elaborated. Table 1 presents the persona characteristics described in each of those techniques. Those characteristics represent the information that should be described during the creation of personas.

Most of the authors did not present experimental studies. Among the techniques cited, we identified a case study only with the technique proposed by Aoyama [19]. In addition, Idoughi *et al.* [18] and Acuña *et al.* [12] presented examples of application modelling using their proposed techniques.

'Problems' characteristics were identified in only two templates, and 'existing solutions' in only one. These two types of characteristics help to find information that is important to the desired application. 'Existing solutions' show information about existing applications that solve problems related to the persona and they can help to identify negative and positive aspects of those applications. 'Problems' describe difficulties that the persona faces and that the application can solve and helps to identify functionalities for the application.

Most of the presented characteristics are related to characteristics of a persona's attitudes (identification, psychological traits, needs and expectations, special needs and accessibility, relationships and interaction with other people, usage context and environment and motivations), i.e. they describe their personal life and psychological traits. These characteristics are important to empathise with the users but they do not identify potential application requirements. The techniques also presented some characteristics (goals, experiences, and skills, used applications and services, tasks, stories/anti-stories, usability preferences) that can help to identify relevant characteristics for the application. However, these characteristics are briefly or vaguely described, i.e. they do not present enough detail; this makes it difficult to identify application requirements. Therefore, many personas created using the existing techniques present information that is not part of the application domain and that does not generate potential requirements.

According to these characteristics, we can observe that, among the investigated techniques, the most detailed one is the technique proposed by Acuña *et al.* [12], i.e. it represents more characteristics than all the other techniques presented in Table 1. We, therefore, chose their technique (presented in the next subsection) to compare with the PATHY technique (presented in Section 3).

Table 1 Characteristics described when creating personas with the presented techniques

Characteristics	Acuña *et al.* [12]	Idoughi *et al.* [18]	Aoyama [19]	Bhattarai *et al.* [20]	Cleland-Huang *et al.* [21], Cleland-Huang *et al.* [22], Rahimi and Cleland-Huang [23]	Khalayli *et al.* [24]	Sim and Brouse [25]
persona identification	X	X	X	X	X	X	X
usage context/environment	X	—	—	—	—	—	X
psychological details	X	X	X	—	—	—	—
used applications/services	—	—	—	—	—	—	—
needs/expectations	X	X	—	X	—	—	—
skills/previous experiences	X	X	X	—	—	—	X
goals	X	X	—	X	—	—	X
special needs/accessibility	X	X	—	—	—	—	—
relationships/interactions with other people	X	X	—	—	—	—	—
motivations	—	—	—	X	—	—	—
usability preferences	—	—	—	—	—	—	X
stories	—	X	—	—	X	—	—
anti-stories	—	—	—	—	X	—	—
what he/she does?	—	—	—	X	—	X	X
roles and tasks	X	—	—	—	—	—	X
problems	—	—	—	—	X	—	X
existing solutions	—	—	—	—	—	X	—
count	**9**	**8**	**3**	**5**	**4**	**3**	**8**

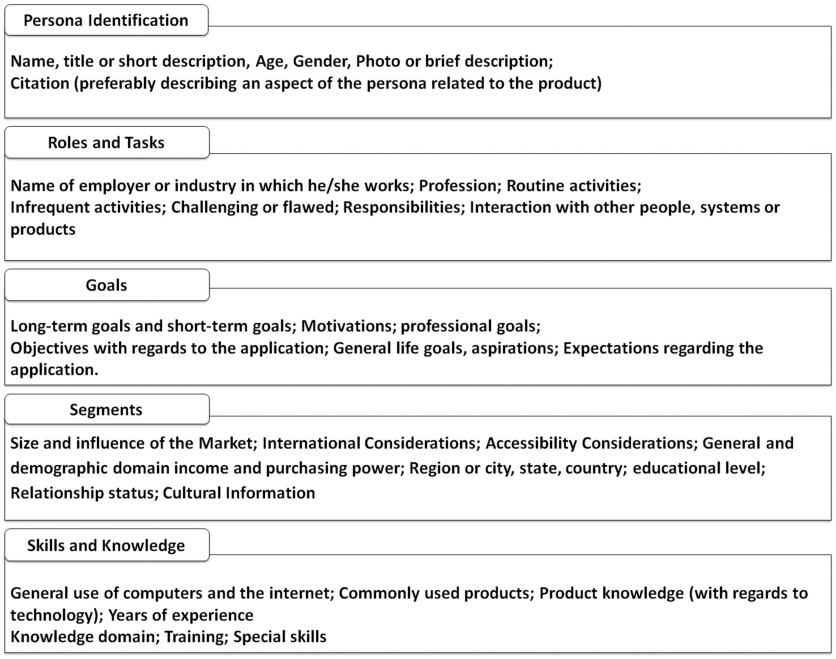

Fig. 1 *Personas characteristics description according to Acuña et al. [12]*

2.3 Personas technique proposed by Acuña et al.

Acuña *et al.* [12] proposed a technique based on the version of the persona creation technique developed by Cooper [16]. The technique aims at the adequacy of personas in software development. As shown in Fig. 1, this technique's template is composed of eight fields (characteristics): persona identification, roles and tasks, goals, segments, skills and knowledge, context/environment, personal, and psychological details. These fields are composed of topics that must be filled in.

The template follows the structure of traditional personas, i.e. it does not have guiding questions to help in the creation of the persona. The technique was chosen because, when compared with the techniques presented in the previous subsection, it contains descriptions of personas with more detailed characteristics, so we considered it the most complete one among them. Furthermore, this technique does not have characteristics with long descriptions. Thus, the technique is similar to PATHY, regarding the size of the template to be filled.

3 PATHY technique

As mentioned above, it is important that both the persona's attitudes and behaviours are described to help build empathy with the users and identify potential and useful application requirements [7]. Therefore, from the characteristics that composed the template of the techniques shown in Fig. 1, we have identified the following limitations: (i) they focus more on empathy than on identifying potential requirements; (ii) the characteristics that help to identify behaviours do not specifically focus on the application domain

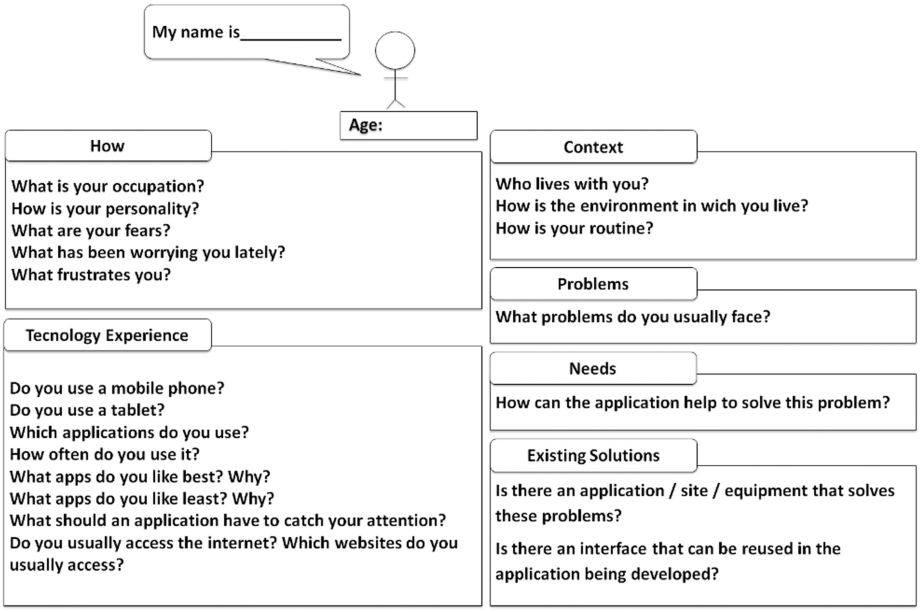

Fig. 2 *Template from PATHY technique with guiding questions*

because those characteristics are not related to the application context.

Consequently, we needed a technique to help guide the personas description focusing on representing and identifying potential requirements related to the domain of the application that will be developed. We, therefore, proposed the PATHY technique [26], which aims to fill that gap and support the identification and representation of potential requirements of an application. These potential requirements represent users' needs. PATHY was proposed based on the empathy map method [27].

According to Caballero *et al.* [28], personas help designing applications through user representations after learning and analysing users' goals and behaviour. The goal of the PATHY technique is to create profiles that represent typical users and their needs. Documents, manuals, or even other software can be used to understand the users' previous experiences, and to enrich the description of profiles with relevant issues for the application that will be designed. In this way, the user profiles created with PATHY will have a greater focus on the software development, leading the stakeholders to think about the application from the users' point of view and to identify potential requirements based on the personas.

The initial version of the technique (PATHY 1.0) was evaluated through a feasibility study [26]. From the results of that study, we generated a new version, PATHY 2.0, which we used in the experiment, reported in this study. Fig. 2 presents the template with the guiding questions of the PATHY technique.

The PATHY technique provides guiding questions to help describe a persona. The guiding questions are grouped in fields, which represent the categories of characteristics that should be described in the persona. The process of creating a persona using PATHY is divided into three phases: (i) knowing the user, (ii) identifying an initial connection between the user and the technology, and (iii) generating ideas. In addition to the empathy phase of DT, in which personas creation is usually inserted, PATHY also covers the definition phase of DT.

The first phase of PATHY involves 'knowing the user'. This phase aims to help the software engineer think about who the user is (through the 'who' field) and the context in which the user is inserted (through the 'context' field). This phase is related to the empathy phase of DT.

The second phase of PATHY proposes an initial link between the user and technology. This phase is supported by the 'experience with technology' field, which aims to lead the software engineer to start connecting the users and the application, describing their previous experiences with technology and other applications. This phase is related to both the empathy and definition phases of DT, as it helps developers to immerse into the user's experience and provide an initial definition of features for the application.

The third phase of the PATHY technique helps to think about the application. This phase aims to generate ideas for the application, focusing on the user. The software engineer is led to focus more on the application (identification of functionalities, similar applications, among others), keeping in mind the user profile that was initially described. This phase is related to the definition phase of DT since some functionalities and characteristics are defined for the application.

PATHY also generates information that can serve as input to the ideation phase. Although this is not PATHY's main goals, in some cases, solutions can be generated to solve the problems the persona faces.

PATHY 2.0 is composed of six fields: who, context, technology experience, problems, needs, and existing solutions. These fields are described next.

Who: Description of the persona who will use the application.
Context: Characteristics of the persona's routine, aspects of the environment in which the persona lives, and people with whom the persona has contact.
Technology experience: Experiences that the persona has had with other technologies or applications, and information regarding application characteristics that the persona likes and does not like.
Problems: Problems faced by the persona and which can be solved by the application to be designed. The goal here is to increase the understanding of the users' issues.
Needs: Needs to be met in order to solve the problems described in the problems field.
Existing solution: Existing solutions related to the ideas and interfaces to be improved or included in the application to be designed for solving the identified problems.

Fig. 3 presents the process of using the PATHY technique. The goal of this technique is to help understand who the users of a certain application are and, from the definition of those users' profiles (the personas), to identify and represent information that helps to generate requirements for an application based on their needs. Personas can be created based on information obtained from users through requirements elicitation techniques (e.g. interviews, questionnaires, and focus groups), meetings between stakeholders or from other sources of research. After the initial research to obtain the data, the personas must be created. From the created personas, potential requirements can be extracted to help the development team understand the users' needs. Those potential requirements can serve as the basis for creating software artefacts, such as requirements list, user stories, or scenarios.

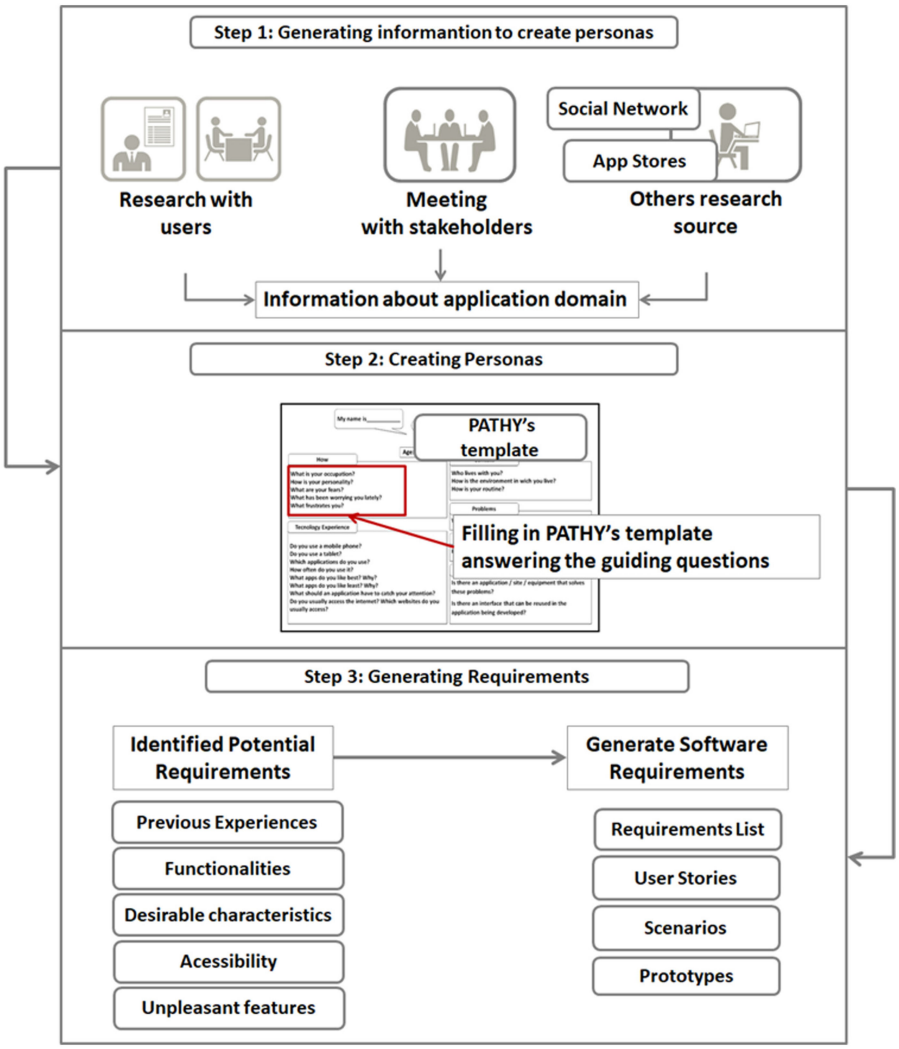

Fig. 3 *Usage process of PATHY technique*

Table 2 GQM of this research objectives

Analyse	PATHY 2.0 and Acuña *et al.*'s technique
for the purpose of	evaluating
with respect to their	efficiency in creating personas with potential requirements
from the point of view of the	researchers
in the context of	computer science and information systems students creating personas for a mobile application

4 Controlled experiment

In this section, we presented the information about the design of the experiment performed in this research. The information described is based on the structure and guidelines presented in Wohlin *et al.* [29] and Jedlitschka and Pfahl [30].

4.1 Problem statement

Personas are usually created with more emphasis on attitudes [11], i.e. personality characteristics of persona and, as a result, their behaviours, which describe the characteristics related to software usage, are described only superficially [11]. Consequently, the descriptions of personas can include a lot of information that does not help directly in the application design (e.g. hobbies, personas' pets) [9].

Solving this problem is important because creating personas more focused on behaviours can help the development team to spend less time creating personas and identifying relevant information to software.

4.2 Research objectives

We conducted a study to compare PATHY and the technique proposed by Acuña *et al.* [12]. PATHY was not compared with elicitation requirements techniques because it focuses on organising and representing the information collected previously using existing elicitation techniques. In this context, PATHY aims to find new requirements based on the initial requirements collected. The description of research objective follows the template of the goal/question/metric (GQM) [31] method. The GQM of this research is presented in Table 2.

The techniques were compared in terms of the types of potential requirements generated in the descriptions of the personas, the efficiency (ratio of the number of identified requirements to the time spent to describe them), and the participants' usage perception of the techniques.

With regard to the generated information, we identified five types of data: (i) previous experiences of the persona with technology (which can help the development team to think about the application design); (ii) potential requirements, which may generate functional requirements; (iii) desirable characteristics; (iv) accessibility; (v) unpleasant features from the point of view of the persona. We also collected the participants' opinions regarding the use of the two techniques.

4.3 Context

Environment: The experiment was performed off-line, in an academic environment.

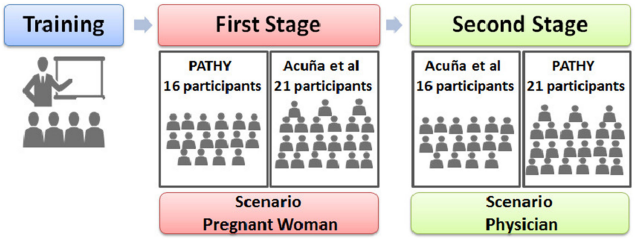

Fig. 4 *Experimental study: stages and scenarios*

Table 3 Examples of potential requirements and software requirements generated from the personas

Potential requirement	Software requirement
Ana is pregnant and does not know what physical exercises she can practice	The app must show which physical exercises can be practiced during pregnancy.
Paul cannot remember details of previous medical consultations, even if using notes.	The app must provide the history of medical consultations.

Subjects: The participants of the study were 37 undergraduate students in their fifth semester of either a computer science course or an information systems course. Students were taking a class on introduction to software engineering. All participants signed a consent form agreeing to provide the collected data for analysis. The participants were selected by convenience sampling, i.e. those taking the class and who accepted to volunteer for the experiment.
Reality: The used scenarios described a real application.

4.4 Variables selection and experimental design

The dependent variable selected was efficiency. The efficiency of the techniques was calculated as the number of potential requirements in each persona divided by the time spent for the creation of the persona.

The independent variables used in this experiment were the techniques: PATHY and Acuña *et al.*'s technique [12]. The experiment design was paired comparison design (cross design), in which all participants used both treatments.

4.5 Hypotheses

The tested hypotheses to analyse the efficiency of the techniques are described below.

H_0: There is no significant difference in terms of efficiency between PATHY and Acuña *et al.*'s technique.
H_1: There is a significant difference in terms of efficiency between PATHY and Acuña *et al.*'s technique.

4.6 Instrumentation

Objects: The object used during the experiment was a scenario based on a real application to monitor pregnant women. In this application, there were two main users: (i) the pregnant woman, who could interact both with the physician to ask questions and with other pregnant women to exchange tips on pregnancy; and (ii) the physician, who could do check-ups on the pregnancy through the application. In this context, the scenario consisted of two parts: the first part described the summary of a pregnant woman's routine and her concerns. The second part of the scenario described the routine of a physician monitoring a pregnant woman. Based on this scenario, the participants created the personas of the pregnant woman and her physician.
Guidelines: To guide the participants, prior to the execution of the study we conducted a training session in the two techniques. During the training session, we also explained concepts related to personas in general. In addition, we presented usage examples of both techniques and practical exercises. All participants attended the same training session, which lasted 1 h and 40 min.

Measurement instruments: The templates of the techniques (Figs. 1 and 2) were used to collect potential requirements to the application. After participants filled the templates, the created personas were analysed to identify the potential requirements described in them.

After using each technique, the participants answered a questionnaire, which included questions regarding the difficulties in using the technique, as well as its positive and negative aspects. After using both techniques, the participants answered a comparative questionnaire. This questionnaire was composed of four multiple-choice questions about Q1 – intention to use the techniques; Q2 – which technique they considered simpler; Q3 – which technique generated more details about the user's personal life; and Q4 – which technique generated more potential requirements for the application. The participants should choose an alternative and justify their choices.

4.7 Experiment execution

The study was carried out in two stages. In the first stage, 16 students used the PATHY technique and 21 students used the technique proposed by Acuña *et al.* [12]. The number of participants in the groups is different because there were participants who did not attend the second stage of the study, so data collected from them were discarded. In the first stage, the participants received a scenario and created personas describing pregnant women.

In the second stage, the 16 participants who had used the PATHY technique used the technique proposed by Acuña *et al.*, and the 21 participants who had used the technique proposed by Acuña *et al.* used PATHY. In this stage, the participants received the same scenario used in the first stage; however, the persona to be described was the physician. As a result, all participants used the two techniques. In total, 74 personas were created. During the creation process, the time taken for applying the techniques was measured. Fig. 4 presents the stages of the experimental study and the scenarios used in each stage.

5 Results

This section presents the results of the study, comparing the content of the created personas, the efficiency, and the participants' perceptions of each technique.

5.1 Analysis of the created personas

This section presents an analysis of the potential requirements identified in the personas. As mentioned before, the potential requirements are characteristics or situations identified through the personas and that help software engineers think about software requirements for the application. Table 3 presents examples of potential requirements of the application for pregnant women and the software requirements generated based on them.

The analysis of the personas aimed to verify which of the two techniques produced more relevant information for the application. In the analysis, we did not consider information regarding the personal characteristics of the user (a persona's hair colour, for example). Instead, we considered only their behavioural aspects, that is, the characteristics that could more directly contribute to the development of the application to be designed.

After the participants created the personas, we analysed all personas in order to verify what types of potential requirements the techniques generated. To do so, one of the researchers extracted the potential requirements of the personas and organised them into groups representing categories of requirements. These potential requirements and their classification are presented in [32].

After the initial grouping, a second experienced researcher grouped the identified requirements according to the defined categories. Each researcher grouped the potential requirements individually. To ensure that the characterisation and classification of an object are reliable, it is necessary to have this object characterised and classified several times, for example by more than one researcher [13]. We calculate the Cohen's Kappa inter-

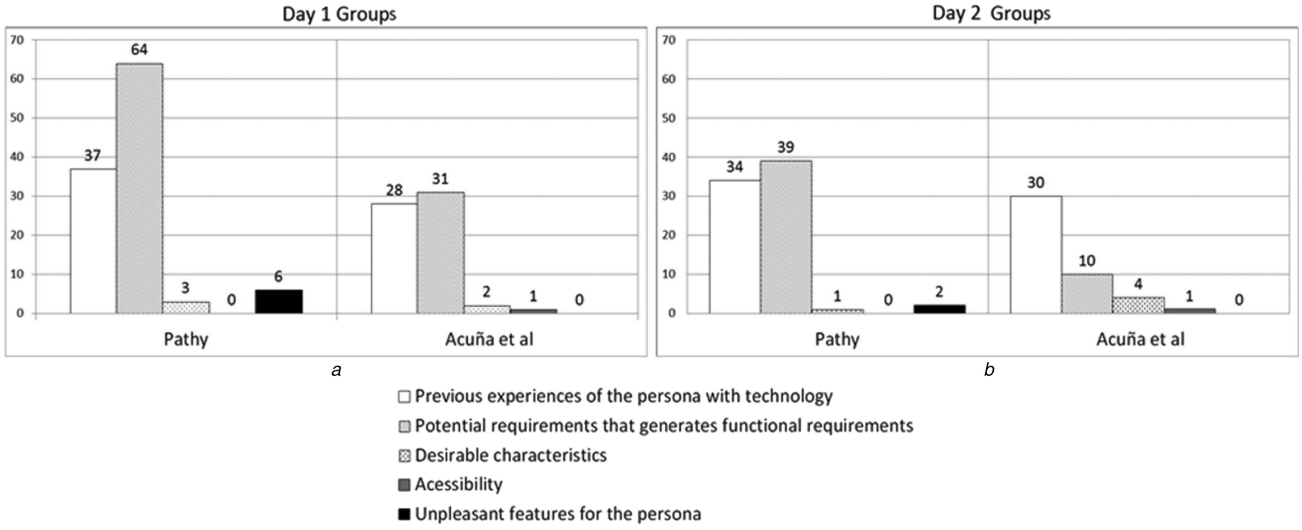

Fig. 5 *Number of potential requirements – part A: day 1 groups (pregnant woman persona) and part B: day 2 groups (physician persona)*

observer agreement measure in order to assess the degree of agreement between the two researchers [33, 34]. To perform the Kappa test we used the SPSS 23 tool [35].

The potential requirements generated in the first day of the study (day 1 group) were grouped separately from the potential requirements generated in the second day (day 2 group), since they represented requirements from different personas: the pregnant woman and her physician, respectively. At the end of the grouping process, the researchers held a meeting to address the disagreements and to reach a consensus on the final grouping of potential requirements and their corresponding categories, described next.

Previous experiences of the persona with technologies: Previous experiences that the persona had with websites, operating systems, use of equipment (tablet, cell phone, and computer), applications or even whether the persona had never had contact with such technologies. These potential requirements can help the requirements engineers to understand whether they are designing for an inexperienced or an experienced user. In addition, by knowing what the persona likes (apps, sites), the software engineer can know with which interfaces this user is familiar.
Potential requirements that may generate functional requirements: Potential requirements that help identify functionalities for an application. Some information describes issues that the persona wants to solve with the app. These problems help to generate features.
Desirable characteristics: Characteristics that the persona would like to have in an application, such as gamification, integration with other applications, and integration with other equipment.
Accessibility: Potential requirements that help to consider accessibility features for the application.
Unpleasant features for the persona: Information about what the persona does not like in applications, websites, and devices. These potential requirements help identify features that should not be added or should be improved in the app being developed.

The Kappa values obtained for the day 1 group and the day 2 group were 0.752 and 0.625, respectively. According to the interpretation of the Kappa results suggested by [34], the results obtained for the two days indicate a significant level of agreement between the researchers. After having grouped the potential requirements, the researchers checked which of them were vague or irrelevant, because those would not help identify software requirements. In the day 1 group, 12 vague pieces of information were identified for PATHY and five for Acuña *et al.*'s technique. In the day 2 group, seven vague pieces of information were identified for PATHY and four for Acuña *et al.*'s technique.

Fig. 5 'part A' presents the types of potential requirements generated on the first day of the experiment related to the personas of pregnant women (day 1 group). In total, 62 potential requirements were identified with Acuña *et al.*'s technique and 110 with PATHY. In the description of the potential requirements examples, the techniques will be represented by the following codes: T1 for PATHY and T2 for Acuña *et al.*'s technique.

The most frequent types of potential requirements in both techniques were 'previous experiences with technology' and 'potential requirements that generate functional requirements'. Some examples of 'potential requirements that generate functional requirements' are the following:

'The physician keeps track of exercises' – T1 and T2.
'The app reports physical exercises that can be practiced' – T1.
'One can keep track of the baby's weight' – T2.

Regarding the requirements of 'previous experiences with technology', PATHY presented more detailed potential requirements when compared with Acuña *et al.*'s technique. In this category, the potential requirements generated with PATHY allow the software engineer to obtain insights about possible interfaces for the application to be designed. Some examples are presented below.

'The app could use the Gmail interface (chat) to ask questions to the nutritionist' – T1.
'It could use Facebook interface to track news' – T1.
'She likes WhatsApp because it allows you to send messages with media' – T1.
'She uses Vade Mecum digital' – T2.
'She uses her cell phone to check news, keep contacts and manage her schedule' – T2.

PATHY did not generate potential 'accessibility' requirements, possibly because the technique does not have guiding questions that focus on accessibility. Acuña *et al.*'s technique did not present potential requirements of the 'unpleasant characteristics for the persona' category. A possible reason may be that it does not suggest including information about what the persona does not like in other applications. The following are some examples of potential requirements of the type 'unpleasant characteristics for the persona'.

'She does not like twitter because she thinks it brings little information' – T1.
'The app cannot have a full menu of options because she knows she will not use everything' – T1.

On the second day of the study (day 2 group), we identified a total of 45 potential requirements with Acuña *et al.*'s technique and 76 requirements with PATHY. Fig. 5 part B presents the number of

potential requirements generated by the techniques by the day 2 group for each category.

With regard to the 'previous experiences with technology' category, the two techniques differed by only four potential requirements. However, the same situation described for the first day of the study happened again: the potential requirements of this category for PATHY were more elaborate.

'The 'Any Do' app helps to track activities, but there is no option for scheduling a query for 30 days later, for example.' – T1.
'The app should allow recording images and relevant measurements. It could have a similar interface to Trello [36] where we can manage checklists and track annotations' – T1.
'It does not have security regarding the use of smartphone' – T2.
'It uses contact and task management applications' – T2.

Similar to what happened on the first day of study, PATHY did not generate potential 'accessibility' requirements. Also, Acuña *et al.*'s technique did not present potential requirements of the 'unpleasant characteristics for the persona' category.

As mentioned above, the presented analysis does not take into account information about the user's personal characteristics (persona's routine, things that the persona does and that are not relevant to the application). However, during the analysis, we could observe some aspects with regard to these characteristics. The technology fields proposed by Acuña *et al.* that generated most of the users' characteristics were: 'objectives', 'context and environment', 'roles and tasks', 'personal and psychological details', and 'persona identification'. These fields have generated many characteristics, describing the routine of the persona and what the persona likes, often losing focus from the application. For example:

'She has her own ice cream shop, she participates in the production process of the ice creams, and her routine is relatively light' – T2 – 'goals' field.
'She does not like the big cities, so the apartment where she lives is acoustically sound proof' – T2 – 'personal and psych ological details' field.

Regarding PATHY, the fields that presented user characteristics were: 'who' and 'context', as expected.

We highlight that the 'context' field, in addition to not presenting any potential requirements (as described previously), has brought many characteristics about the personas' personal details. The following are some examples:

'She lives with her husband and has a busy routine due to her work.' – T1 – context field.
'Later in the afternoon, her husband picks her up and they go home.' – T1 – context field.

These personal details of the user, generated by the two techniques, are important for the development team to create empathy with the users because these details allow the team to think as if they were in user's shoes to understand their point of view. However, the excess of detail of this information may create user profiles that are aimed more at achieving empathy with the users than at identifying potential requirements for the application.

5.2 Efficiency of the techniques

We used the time that each participant took to use each technique and the number of relevant potential requirements found [32] per participant to calculate the efficiency (number of relevant potential requirements found per hour). Table 4 summarises the results for each participant. Group A used the technique proposed by Acuña *et al.* first and Group B used the PATHY technique first.

To compare the samples, we used the paired *t*-student test with a confidence level of 0.05. We selected the paired *t*-student test based on the results of the Shapiro–Wilk normality test [37], which indicated that the data (efficiency values) were normally distributed. We performed the statistical analysis using the SPSS tool.

As a result of the paired *t*-student test we obtained a *p*-value <0.001, rejecting the null hypothesis. Therefore, there was a *significant difference in the efficiency* of the techniques. PATHY was more efficient than the technique proposed by Acuña *et al.*'s technique.

Table 4 Summary of efficiency results per participant and technique

Day 1 group								Day 2 group							
Acuna *et al.*				PATHY				PATHY				Acuna *et al.*			
P	PR	T	E	P	PR	T	E	P	PR	T	E	P	PR	T	E
1	06	0.38	15.79	22	10	0.53	18.87	1	09	0.37	24.32	22	04	0.97	4.12
2	04	0.42	9.52	23	15	0.52	28.85	2	09	0.42	21.43	23	10	0.67	14.93
3	11	0.38	28.95	24	20	0.67	29.85	3	09	0.22	40.91	24	06	0.83	7.23
4	11	0.43	25.58	25	18	0.55	32.73	4	04	0.25	16.00	25	07	0.55	12.73
5	08	0.83	9.64	26	12	0.50	24.00	5	15	0.58	25.86	26	10	0.68	14.71
6	12	0.53	22.64	27	13	0.58	22.41	6	08	0.35	22.86	27	07	0.65	10.77
7	09	0.42	21.43	28	14	0.75	18.67	7	09	0.42	21.43	28	06	0.58	10.34
8	10	0.60	16.67	29	09	0.72	12.50	8	09	0.47	19.15	29	05	0.58	8;62
9	07	0.62	11.29	30	14	0.33	42.42	9	06	0.43	13.95	30	06	0.37	16.22
10	10	0.52	19.23	31	07	0.48	14.58	10	05	0.38	13.16	31	03	0.43	6.98
11	04	0.65	6.15	32	16	0.50	32.00	11	08	0.47	17.02	32	06	0.50	12.00
12	08	0.62	12.90	33	08	0.45	17.78	12	06	0.65	9.23	33	07	0.42	16.67
13	09	0.72	12.50	34	13	0.30	43.33	13	10	0.58	17.24	34	09	0.50	18.00
14	05	0.52	9.62	35	10	0.50	20.00	14	05	0.53	9.43	35	02	0.32	6.25
15	06	0.65	9.23	36	13	0.33	39.39	15	10	0.37	27.03	36	07	0.50	14.00
16	07	0.82	8.54	37	12	0.57	21.05	16	09	0.45	20.00	37	05	0.50	10.00
17	08	0.82	9.76	—	—	—	—	17	08	0.25	32.00	—	—	—	—
18	07	0.97	7.22	—	—	—	—	18	09	0.43	20.93	—	—	—	—
19	08	0.77	10.39	—	—	—	—	19	11	0.60	18.33	—	—	—	—
20	07	1.02	6.86	—	—	—	—	20	13	0.78	16.67	—	—	—	—
21	10	0.88	11.36	—	—	—	—	21	10	0.63	15.87	—	—	—	—

P, participant; PR, number of potential requirements found; T, time spent in hours for using the technique; E, efficiency (number of potential requirements found per hour).

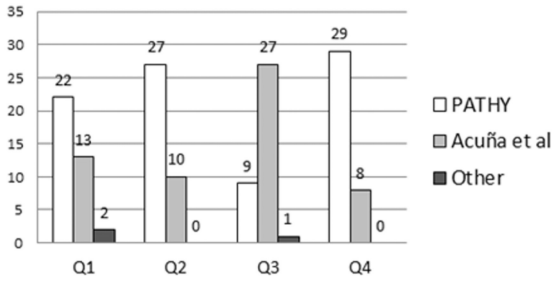

Fig. 6 *Questionnaires' results*

5.3 Perception regarding the use of the techniques

We carried out two analyses to evaluate the participants' perceptions of the techniques: (i) qualitative analysis and (ii) quantitative analysis. We performed the quantitative analysis by quantifying the answers of the comparative questionnaire. In this analysis, we counted the number of participants who chose each alternative. This questionnaire comprised four questions: (Q1) intention to use the techniques; (Q2) simpler technique; (Q3) technique that generates more details about the personal life of the user (attitudes of the persona); and (Q4) technique that generates more potential requirements for the application (behaviours of the persona). Fig. 6 presents the summary of the obtained results.

The participants considered PATHY simpler and also showed higher intention to use it. In addition, the participants also stated that the technique helped them think of more features for the application than Acuña *et al.*'s technique. On the other hand, Acuña *et al.*'s technique helped the participants think of more personal details of the user, which are not relevant for the development of the application but help increases empathy.

We also performed a qualitative analysis based on coding procedures, i.e. by assigning meaning to the data [43]. We conducted a qualitative analysis of the answers given in the specific questionnaires and on the justifications of the answers to the comparative questionnaire. As we analysed the data contained in the questionnaire, we created codes associated with fragments of the text. Another researcher verified the codes and categories to validate the coding process and mitigate the bias caused by the participation of a single researcher in the coding process. The results of this analysis are presented next.

According to the participants' perception, Acuña *et al.*'s technique generates more information related to the personal details of the user's life:

'(…) it makes you put yourself in the user's shoes and really understand their needs.' – P07
'(…) it extracts the most from both personal and professional user characteristics, focusing on it.' – P25

Still, with regard to the technique proposed by Acuña *et al.* [12], some participants considered that generating more information about the user may not be positive:

'The technique is a lot about the 'personas' and their experience with technology, but they lack more details about the application to be developed.' – P31

On the other hand, PATHY helps find more information related to the application:

'The second part of the technique makes you focus on the functionalities first (to identify features for the app).' – P20

According to the participants, PATHY helps to find more requirements for the application than Acuña *et al.*'s technique because it deals directly with the problems and needs of the persona (see the quotation from P31 and P15a). In addition, it also deals with the persona's preferences and applications that are similar to the application that will be developed (see quotations from P15b and P12):

'PATHY asks more about problems, needs and solutions; (…) the other technique does not have this.' – P31
'With existing requirements, problems and solutions, you can view the required requirements.' – P15a
'(…) the technique proposed by Acuña does not mention another application that could help in the creation of the app.' – P12
'(…) with the PATHY we may have experience or examples of similar apps.' – P15b

According to the participants, both PATHY and Acuña *et al.*'s technique help to identify functionalities of the application (see the quotation from P01). In addition, since it helps to think about similar applications, PATHY better supports application designs (see the quotation from P07):

'PATHY defines the persona well and makes a brief analysis of the real needs that the application should fulfil and associates them with existing applications. This greatly helps in the development of both the features and the design of the application being developed.' – P07
'(…) the technique can define the functionalities very well making you think as the user (referring to the technique proposed by Acuña *et al.*).' – P01

With regard to the process for creating personas, the participants found the structure of PATHY easier than the structure of Acuña *et al.*'s technique. The main reason was the guiding questions which PATHY provides:

'In PATHY, just answering the questions is easier than thinking about topics (referring to the technique proposed by Acuña *et al.*).' – P07
'(…) the questions guide well regarding what I should imagine about the persona.' – P16

Some participants considered that Acuña *et al.*'s technique should have guiding questions similar to PATHY:

'More well-defined questions would help in the creation of the persona with the technique proposed by Acuña *et al.*' – P12
'I think it's a little bit harder because we do not have questions.' – P26

We identified that the 'existing solutions' field in PATHY raises difficulty if the software engineer does not know the domain of the application to be developed:

'I had difficulty in the part of existing solutions because I did not have many examples to write about.' – P07
'(…) for the persona's applications it is still necessary to know the area of the application (talking about the definition of applications that the persona likes).' – P33

However, the use of the 'existing solutions' field provides a guide for the search of this information contributing to the design/development of the interface of the application:

'(…) the use of similar application interfaces can contribute significantly to the development of the application (referring to PATHY).' – P12

6 Threats to validity

We describe in this section the threats to the validity of our study that we identified.

Internal validity: There could be an effect caused by the training if the training of Acuña *et al.*'s technique was inferior to the one of the PATHY techniques. To address this threat and the resentful demoralisation threat, we prepared equivalent training for both techniques, using similar examples, and all participants attended the same training session. Another threat concerns the measurement of time not being accurate. To reduce such a threat, the participants were asked to write down the time as accurately as

possible and it was checked at the beginning and end of the experiment whether participants were doing so. Another threat involves the different scenarios: the scenario used as the basis for creating the personas on the first day could not be equivalent to the scenario used on the second day of the experiment. To reduce this threat, the two scenarios for creating the personas were based on the same application; however, the described individuals were different users (pregnant woman and her physician). There could also be learning effects due to the order of using the techniques. To avoid such a risk, all participants used the two techniques, but in a different order. Some participants who participated in the first day of the experiment did not participate in the second day; the data of these participants are discarded.

External validity: The study participants were undergraduate students. This could affect the generalisation of the results because students may not adequately represent industry software engineers. However, it has been shown that, in a specific context of requirements engineering, students have a good view of how the industry behaves and can work well in empirical studies in this area [38]. Furthermore, studies [39, 40] showed that students can adequately represent a population of novice practitioners from the industry. Another threat is that the study was carried out in an academic environment. However, the scenario used was based on a real application that was previously developed. Finally, it is not possible to state that the applied scenario represents all types of scenarios for different applications, and this is a limitation on the results.

Construct validity: A possible threat is the adopted efficiency metric. To reduce this threat, the efficiency metric was based on the concept of efficiency used in other experiments [41]. The adopted efficiency metric considers if the potential requirements are adequate, similarly to [42]. Also, in the analysis of the potential requirements, two independent researchers grouped the requirements, to reduce the experimenter expectancies, and we calculated the Kappa of the agreement between them to evaluate the reliability of the performed grouping.

Conclusion validity: The sample size is not ideal from a statistical point of view. Another potential threat is the subjectivity in the analysis of the qualitative data. This threat was reduced by having a second researcher analysing the obtained results in the qualitative analysis of the participants' answers. The measure of efficiency used in the experiment may not be reliable. To reduce this threat, the relevance and classification of potential requirements extracted from personas were analysed by two researchers and after this, we conducted meetings in order to address disagreements. The differences among participants' previous experience may influence experiment results. To reduce this threat we selected a homogeneous pool of participants. The small sample size can reduce the statistical power of the results. To reduce this threat, we chose a paired comparison design to increase the number of data points for each technique.

7 Conclusion

According to the results of the study, most participants considered that Acuña *et al.*'s technique [12] generates more information about the user, whereas the PATHY technique generates more features about the application. In addition, the analysis of the personas performed by the researchers showed that PATHY found more potential requirements than Acuña *et al.*'s technique. Thus, there are indications that PATHY supports describing personas with a greater focus on identifying characteristics that contribute to application design.

According to the participants' perception, through the 'experience with technology' and 'existing solution' fields (the applications that the persona likes and does not like), PATHY helps to think about potential application requirements. In the analysis of the personas, we observed that the Acuña *et al.*'s technique also generates some information about similar applications. However, the information generated by PATHY is more detailed. In PATHY, besides mentioning other applications, the interface aspects that can generate requirements for the application to be designed are described. However, one difficulty reported by the participants is that there is a need to conduct research to find similar applications, as they are not always known.

Regarding the use of the techniques, both in the quantitative and qualitative analyses, we observed that the structure of PATHY and its guiding questions facilitate the creation of personas. Regarding the efficiency metric, the null hypothesis was rejected, showing that PATHY was more efficient than Acuña *et al.*'s technique.

Despite its benefits, PATHY still needs some improvements so that the generated information is more complete. In the future, the technique will be improved based on the participants' comments and will be evaluated to verify that the generated personas contain complete information to assist the software engineers in the software developing process.

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