IET Software

Research Article

IET Journals
The Institution of Engineering and Technology

Requirements elicitation techniques: a systematic literature review based on the maturity of the techniques

ISSN 1751-8806
Received on 28th June 2017
Revised 22nd January 2018
Accepted on 29th March 2018
E-First on 16th May 2018
doi: 10.1049/iet-sen.2017.0144
www.ietdl.org

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Abstract: Requirements elicitation is a critical activity that forms part of the requirements engineering process because it has to discover what the software must do through a solid understanding of the wishes and needs of the various stakeholders and to transform them into software requirements. However, in spite of its relevance, there are only a few systematic literature reviews that provide scientific evidence about the effectiveness of the techniques used to elicit software requirements. This study presents a systematic review of relevant literature on requirements elicitation techniques, from 1993 to 2015, by addressing two research questions: Which mature techniques are currently used for eliciting software requirements? and Which mature techniques improve the elicitation effectiveness? Prior literature assumes that such 'maturity' leads to a better-quality understanding of stakeholders' desires and needs, and thus an increased likelihood that a resulting software will satisfy those requirements. This research paper found 140 studies to answer these questions. The findings describe which elicitation techniques are effective and in which situations they work best, taking into account the product which must be developed, the stakeholders' characteristics, the type of information obtained, among other factors.

1 Introduction

Requirements engineering (RE) is one of the most difficult areas within the software development process because it decides and defines what has to be developed [1, 2]. Thus, RE is one of the branches of software engineering that arose from the need to solve the difficult tasks of collecting, analysing, and verifying the software requirements [3]. According to Christel and Kang [4], Kotonya and Sommerville [5], and Berenbach *et al.* [6], the RE process is frequently described by the following activities: elicitation, analysis, specification, validation and verification, and management. This study is focused in the first stage of RE, requirements elicitation, where almost all the RE's time is occupied by diverse problems when stakeholders interact to obtain quality requirements [4, 7, 8]. Moreover, within the requirements elicitation process, there is a set of necessary activities: the stakeholder identification and the negotiation and selection of techniques to elicit the wishes and needs of the various stakeholders [4]. In this context, there are diverse techniques for discovering and obtaining the software requirements, but it is necessary to have the knowledge to identify which ones are the most suitable for a specific project [9]. Thus, considering that in order to improve software quality, it is necessary to improve the quality of the obtained requirements, it is crucial to improve the selection of the techniques used by the requirements engineer to discover the stakeholders' needs.

From this perspective, it is important to consider that requirements elicitation does not just happen by itself. This process is strongly related to the context in which it is carried out, the specific characteristics of the project, the organisation, the environment, the experience, and knowledge of the analyst, as well as the characteristics of the elicitation technique employed.

Therefore, in this paper, we present and discuss our experiences of applying the systematic literature review (SLR) in order to gather and evaluate available evidence to help the requirements engineer to select the proper technique for requirements elicitation.

This paper is organised as follows: Section 2 examines other approaches related to SLR on requirements elicitation. Section 3 describes the methodology used to perform the systematic review. Section 4 presents the results obtained by answering the established research questions. Section 5 shows findings obtained from the false positive studies. Section 6 summarises the main conclusions of this paper and some future work. Finally, Section 7 presents the references analysed in our study.

2 Related work

Nowadays, there are some systematic reviews related to the activities of the requirements elicitation process (e.g. [10–13]) and just a few related to the effectiveness of the requirements elicitation techniques and their characteristics (e.g. [14–17]). These studies are briefly described below.

Davis *et al.* [14] presented a systematic review of empirical studies about the effectiveness of elicitation techniques. This study has addressed one particular research question: What is the most efficient elicitation technique in a particular setting? The most significant results can be summarised as follows: (i) the interviews, mostly structured, may be one of the most effective techniques; (ii) many techniques usually cited in literature (e.g. card sorting, ranking, and thinking aloud) are less effective than interviews; (iii) the requirements engineer's experience does not appear to be a relevant factor; and (iv) the analysed studies do not show positive effects when prototyping is used during the elicitation. Taking into account these results, this research paper concludes that interviews are the most effective technique because they enable analysts to obtain more information than the other analysed techniques.

Moreover, Dieste *et al.* [15] generated knowledge about the applicability of elicitation techniques by aggregating the results of existing empirical studies. The authors provide some recommendations about the situations, where the requirements elicitation techniques are useful. These recommendations are the result of an SLR carried out to answer the following research question: What elicitation techniques are most effective? The achieved findings state that: (i) the efficiency of structured interviews technique is more than the scaling techniques; (ii) the scaling techniques and the laddering technique have the same efficiency; (iii) the scaling techniques are more difficult to use than the unstructured interviews; (iv) the unstructured interviews are easier to use than the laddering technique; and (v) the scaling techniques and the laddering techniques present the same difficulty when used. This research paper agrees that, according to the analysed evidence, interviews are more effective for many

situations (e.g. if the requirements engineer is novice or experienced, when the work is performed on new application domains, where there are domain experts etc.), because they extract more information and the information is more complete.

Research by Svensson *et al.* [16] introduces an SLR in order to identify empirical studies focused on quality requirements. This research identifies 156 studies from which 18 studies were classified as empirical research of high quality (according to the research criteria). The research questions established by the study were the following: What empirical research has been performed on quality requirements in relation to elicitation, prioritisation, cost estimation, dependencies, and metrics? What empirical methods have been used to evaluate the quality requirements? The obtained results of the SLR suggest five techniques for eliciting quality requirements: use of lexicons in conceptual modelling, structured interviews, structured hierarchical interview for requirements analysis, workshops, and questionnaires. Moreover, these results state that: (i) quality requirements should not be addressed within the scope of functional requirements because they need a more detailed analysis; (ii) elicitation and architecture must be related because the refinement of quality requirements is not possible without detailed functional requirements and software architecture; and (iii) it is necessary to analyse the interdependencies between quality requirements and the software design in order to ensure a basic understanding of the problem. Finally, this paper supports the notion that there is no one unified way for eliciting quality requirements.

Finally, Dieste and Juristo [17] show the results of an SLR over 564 empirical studies on elicitation techniques. This study selected and extracted information from 26 studies (30 empirical studies) to test 43 elicitation techniques (e.g. interviews, questionnaires, introspective techniques, prototyping, scenarios, and more) and 50 different response variables (e.g. customer needs, requirements number, objectives number, processes number, tasks number, type of knowledge, and efficiency). The findings are summarised in five guidelines: (i) unstructured interviews are more effective than introspective techniques and sorting techniques; (ii) the information obtained from unstructured interviews is more complete than that obtained from introspective techniques, sorting techniques, and laddering; (iii) unstructured interviews are less efficient than sorting techniques and laddering, but as effective as the introspective ones; (iv) introspective techniques gave the worst evaluated for dimensions such as effectiveness, efficiency, and completeness; and (v) it is recommendable to use the laddering technique instead of sorting or introspective techniques. From this evidence, the research states that interviews are the most effective technique though it may be less effective in other domains compared with other techniques such as laddering and sorting techniques (e.g. when stakeholders have no experience with the problem that needs solving), and it is not recommended to use the introspective techniques such as the protocol analysis, because these do not show good results for the evaluated dimensions.

In summary, the above-related work provides evidence of systematic reviews focused on analysing theoretical and empirical studies comparing different elicitation techniques from different researchers' points of view. Nevertheless, unlike these related works, in this paper, we present and discuss our experiences of applying the SLR in order to evaluate which mature techniques for requirements elicitation are more effective under certain circumstances, as well as those characteristics that influence their effectiveness. With this aim in mind, our efforts are focused on providing the requirements engineers with a guide to select the appropriate elicitation technique based on the issues previously mentioned. It is important to mention that our premise is that these aspects can lead to an improvement in the understanding of stakeholders' needs, and thus an increased likelihood that a resulting system will satisfy those needs.

3 Research method

According to Kitchenham *et al.* [18], an SLR is 'a media to evaluate and interpret all the relevant information available for a research question, topic of a particular area, or interest phenomenon'. In this regard, an SLR has the objective of presenting an evaluation of the literature related to a research topic using the synthesis of a rigorous methodology [19]. This study follows the guidelines derived from those used in medical research, adapted and applied by Kitchenham to software engineering [18, 20] and the guideline proposed by Kuhrmann *et al.* [21] to identify which techniques are most used and are most effective in requirements elicitation. Thus, according to Kitchenham [18] and Kitchenham *et al.* [20], an SLR must follow the steps presented in the following sections.

3.1 Identify the necessity for an SLR

Owing to the impact of RE in software quality, it is important to mention that one of the main causes of failure of software projects is the inability to obtain complete, correct, and unambiguous requirements. In other words, it is necessary to 'elicit high-quality requirements' [5, 22–25]. The role of the requirements elicitation process is essential because it conceptualises the software in terms of what the stakeholders really need and not what they wish for. In this regard, the knowledge of the application domain, of the context, and of the problems solved by the software is also required [4]. Moreover, the elicitation techniques are used to obtain the stakeholders' information, knowledge and needs required for developing quality software. Although there are many elicitation techniques, there is no uniform or standard guideline for selecting them and, therefore, it is very difficult to select the one that best fits the project taking into account its own characteristics. As a consequence, the elicitation process is wrongly executed no matter that the stakeholders have been correctly identified, and it is impossible to ensure that the obtained information by the process is useful, correct, and complete. Some empirical studies (e.g. [26–28]) have suggested that the techniques selection should be done taking into account the software that will be developed, the project status, the application domain, some anomalies that may occur, the advantages of each technique, and the information that these can provide. Moreover, Hickey and Davis [26] argued that analysts select a particular elicitation technique due to one or more of the following reasons: (i) it is the only technique that the analyst knows, (ii) it is the analyst's favourite technique for all situations, (iii) the analyst is following some explicit methodology, and that methodology prescribes a particular technique at the current time, and (iv) the analyst understands intuitively that the technique is effective in a particular context. The specialised literature indicates that those techniques that best fit the project's purpose and the different types of information should be selected; thus, it is highly recommended to choose many techniques [28]. Each elicitation technique can provide a specific type of knowledge and each one has unique characteristics that make it effective in specific cases [27, 28]. Nevertheless, most practising requirements engineers do not have the necessary insight to make such an informed decision, and therefore rely on their experience or their instincts. In this context, it is necessary to evaluate the effectiveness of each technique to identify which characteristics can influence its performance and how to measure the quality of the obtained requirements.

According to Harter *et al.* [29], in manufacturing, for example, there is evidence that process maturity (i.e. the sophistication, consistency, and effectiveness of manufacturing processes) is positively associated with product quality. It is believed that this relationship exists because as a process becomes more mature and less variable, the outputs of the process (i.e. products) have a higher level of quality. In the context of software production, this implies that maturity of any software development process is essential reducing process variability and thus improving the quality of software products. For this reason, it is important to identify mature elicitation techniques in order to recognise those that have proved to be effective, and to obtain information about the characteristics that affect their ability to elicit quality requirements.

In this regard, according to Christel and Kang [4], a criterion for deciding on the techniques' maturity states that these had to be applied, tested, or used in development projects for at least a

decade (i.e. it is necessary to have a historical record evidencing the use of the technique in software requirements elicitation). Also, research by Jiang *et al.* [30] argues that a technique is mature if it is well-defined by a set of systematic steps or notations, it is well organised and documented, and it has been used in industrial environments; thus, it can be ensured that there is enough information for the analysis of techniques for a research project. Therefore, an SLR enables us to: (i) collect evidence from the existing studies focused on the techniques used in the requirements elicitation process, as well as their effectiveness; and (ii) find information related to characteristics that may improve the requirements elicitation process and thereby the RE process.

3.2 Define the research questions

The systematic approach used to analyse published studies enables us to identify the relevant literature that exposes the different mature techniques currently used in the requirements elicitation process. With this aim in mind, we analysed these techniques to determine which characteristics influence their effectiveness in eliciting requirements. In this regard, it was necessary, therefore, to perform a systematic search of the literature in order to answer the following research questions:

Research Question 1 (RQ1): Which mature techniques are currently used for eliciting software requirements?
Research Question 2 (RQ2): Which mature techniques improve the elicitation effectiveness?

Regarding to RQ2, according to the thesaurus dictionary, the 'effectiveness' term means 'adequate to accomplish a purpose; producing the intended or expected result'. Also, for Davis *et al.* [14], effectiveness for an elicitation technique is to identify under what conditions it would be best to apply one particular elicitation technique or, alternatively, find out which is likely to be the best elicitation technique for a specific situation.

3.2.1 Establish the search terms: From the previous research questions, the following keywords were derived: '*requirements*', '*eliciting*', '*techniques*', '*effectiveness*', and '*characteristics*'. The search strings were constructed using relevant terms based on the two research questions. Also, we made a list of synonyms of each of these keywords, as in the example for RQ1, which contains keywords '*eliciting*' and '*requirements*':

Keywords (techniques) AND (eliciting OR obtaining* OR gaining* OR extracting* OR acquainting* OR discovering* OR capturing* OR gathering*) AND (requirements* OR needs* OR demands* OR necessities*).*

Additionally, these search terms were expanded using Word Net version 3.0 [31], thesaurus and Soule's dictionaries of English synonyms. Thus, the list of search terms has been adapted to match each of the research questions.

3.3 Define the searching strategy

The process of performing an SLR recommends researching different electronic sources [18, 32], so we have used the following research databases:

- ACM Digital Library.
- IEEE Xplore.
- Springer Verlag.
- Google Scholar.
- ScienceDirect.
- Metapress.
- Wiley InterScience.

To identify research papers and locate potentially relevant studies (i.e. from industrial and academic contexts), the searching strategy of this review was focused on discovering published papers (e.g. journals, conference proceedings, technical reports, and books) in the previously mentioned research databases. Trial searches were performed using search strings constructed by the combination of the keywords and synonyms previously mentioned.

3.4 Select studies

The selection of material for the SLR was based on the following criteria and procedures.

3.4.1 Establish the criteria for studies selection: The main criterion to include a paper as a primary study was related to the presentation of empirical or practical data on the effectiveness of techniques used in the requirements elicitation stage. In this regard, all the material included in the SLR was selected according to the following inclusion criteria (e.g. books, proceedings, papers, and book chapters):

- That it directly answers one or more of the research questions.
- That it has been published between 1993 and 2015. In this regard, 1993 was chosen because in this year the first RE symposium was held.
- That it was related to any technique for requirements elicitation.
- That it contains data about the technique's ability to achieve the expected effect on requirements' quality.

Since the focus of this literature review is the elicitation techniques and their effectiveness, the following material was excluded:

- Slide presentations.
- Workshops (editorials and papers).
- Personal opinions, points of view, or anecdotes.
- Tools without empirical evaluation of their use.
- Out of the software engineering field.

3.4.2 Define the procedure for studies selection: The preliminary selection of candidate primary studies was initially based on the analysis of title, abstract, and keywords, though this search was extended to include the conclusions section of each study when the title, abstract, or keywords did not provide sufficient information. All the selected sources were then analysed against the detailed set of inclusion criteria in order to obtain the primary studies. With the aim of avoiding any repetition, it was necessary to carefully review all the studies to find repeated publications, thus if a similar study was presented in different publications (even with different authors), only the most recent and broadest study was included in the review, or if two studies had the same publication date and the same extension regarding the topic scope, only one study was considered.

3.5 Evaluate the quality of the selected studies

The evaluation of quality over the selected studies can be used to lead the synthesis' interpretation of the achieved findings and to determine the strength of the elaborated inferences [32]. The quality of each accepted study was evaluated taking into account the criteria shown in Table 1. The first criterion enabled us to evaluate whether the study authors had clearly achieved the purposes and objectives of the performed research (this question was positively answered by all the reviewed publications). The second criterion enabled us to evaluate whether the studies had provided sufficient information (either directly or by referencing other relevant literature) to establish the context and background for our research; the evaluation was positive for almost all the publications (95%). The last criterion enabled us to evaluate if the outcome of the research was sufficient for our research purpose [this question was positively answered by almost all the publications (97%)].

The evaluation measures were established by three experienced researchers from the Universidad Tecnologica de la Mixteca and validated by an independent researcher. The independent researcher was not part of the paper authors. His expertise is in the field of RE, specifically in requirements elicitation and he has also

Table 1 Quality evaluation

Evaluation criterion	Answer option for scoring (field in endnote)	Score
is the aim of the research clearly explained?	yes = 1/moderately = 0.5/no = 0	—
is the presented approach clearly explained?	yes = 1/moderately = 0.5/no = 0	—
for this study, what is the acceptance quality rate based on the findings?	not findings or under 20% = 0/over 80% = 1/between = 0.5	—
%	enter the percentage for the quality evaluation flown in endnote	—

Table 2 Quality scores for the accepted studies

	Scores for quality					
	Poor (<26%)	Fair (26–45%)	Good (46–65%)	Very good (66–85%)	Excellent (>86%)	Total
number of studies	15	19	35	45	26	140
percentage of studies, %	~10.71	~13.57	~25	~32.14	~18.57	100

Table 3 Validated and reviewed studies

Selection process	Number of studies	Studies used in the validation
studies that were extracted from research databases	270	n/a
studies examined based on title and abstract	172	n/a
studies accepted by primary researchers	153	—
studies rejected by the independent researcher (validation 1)	139	14 studies rejected from the 90 studies that were randomly selected and that were part of the 152 accepted studies
studies added by the independent researcher (validation 1)	147	8 studies added out of the 90 studies that were randomly selected and rejected by the primary researchers
studies rejected by validation 2	140	seven rejected

authored other SLRs. Additionally, the three researchers carried out the process of evaluating the papers' quality. However, the scoring is only a heuristic that is used as a guide and no study was rejected on the basis of its quality score. Thus, data from 140 studies was normalised by combining the percentage obtained with the quality criterion (see Table 2).

3.6 Define the strategy for data extraction

According to Beecham *et al.* [19], each study used to answer the research questions should be recorded on separate results form in order to identify the topics obtained from the findings achieved in each accepted study. The data extraction process was carried out by using Endnote version X6 to document the references for each study. In our case, the identified topics generate the categories reported in the results section of this paper.

3.7 Synthesise the extracted data

The Kitchenham's guidelines are not altogether clear about the nature of the extraction process – how much categorisation is done during the data extraction and how much in the data synthesis. We, therefore, decided to conduct a trivial data extraction that enabled us to obtain a list of quotes that were minimally paraphrased. This categorisation was done in the early steps of the synthesis stage. Thus, Section 4 shows the frequencies for each theme identified in different sources; each occurrence received the same weight. The frequencies reflect how many times a given issue is identified in different studies and not how relevant it may be.

3.7.1 Retrieve the documents: The searches enabled us to obtain 270 references, and by analysing the title and abstract we rejected ~98 of these (see Section 3.4.2).

We can confirm that the number of false positives in the initial set was not high (i.e. studies that may have been relevant, but after a detailed research, it was decided that they were not relevant as they were focused on tools that support the elicitation techniques or studies that did not include a study case). Therefore, a careful review of 172 studies led us to establish a final list of 140 studies. Table 3 provides a description of the steps related to the selection process.

Moreover, our validation exercises include the following:

- *Validation 1 – Inter-rater agreement*: According to Fleiss' Kappa [33], the inter-rater agreement depicts the consistency of the data extraction among the analysed studies when two or more researchers evaluate each study. Thus, an inter-rater agreement test was conducted on the 172 studies found in the preliminary search. The primary research group, composed of experts from the Universidad Tecnologica de la Mixteca, carefully analysed each one of these studies. These researchers accepted 153 studies, while the independent researcher randomly analysed 90 studies chosen among those rejected and accepted (approximately one of each two studies from a list in alphabetical order of 172 studies) and 91% conformity was recorded by the original evaluations. This percentage of the agreement provided certainty to the acceptance and rejection decisions.
- *Validation 2 – Independent evaluation*: This exercise was conducted over the 153 accepted studies and a high percentage of agreement (92%) between primary researchers and the independent expert was obtained. However, there was a disagreement in eight of the accepted studies and it was necessary to reject seven studies in the opinion of a second independent researcher. As a result of the validation, 140 studies were accepted for our research.

It is important to mention that, due to the unstructured sources and the high level of heterogeneity of the analysed studies, it was impossible to apply the meta-analysis techniques such as the data aggregation [32].

4 Results

Our search found a total of 140 studies about the techniques that have been used for the period 1993–2015 on requirements elicitation process by academics and industry practitioners. Some of these studies identify which techniques are more useful in specific situations, while others highlighted the characteristics that promote their advantages. The bibliography references for these 140 studies are provided in the references section (some studies answered more than one research question or have covered diverse aspects related to these questions). Before analysing in detail, each research question and presenting the obtained results, we first provide an overview of the general characteristics of the studies.

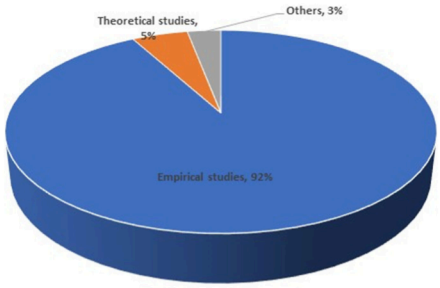

Fig. 1 *Research methods in the accepted studies*

4.1 Overview of the selected studies

4.1.1 Research method: The analysed studies were directly classified by the research method employed. The initial strategy for categorisation was simple: to use the research method without interpreting the study content. The studies were classified by taking into account the International Software Engineering Research Network (ISERN) [34] recommendations as follows:

- *Empirical*: Those studies whose findings were based on direct evidence, experiments, or case studies.
- *Conceptual or theoretical*: The studies' findings that were based on the comprehension of the experience field and quote other related work.
- *Others*: Either reviews of the literature or secondary studies, where empirical work is re-examined.

Therefore, Fig. 1 depicts that from the 140 studies, 92% are empirical (mostly case studies), 5% are theoretical, and a small number of studies (3%) are within the others category. Moreover, 55.8% of the empirical studies came from academic experiences, 38.8% were related to industrial experiences, and 5.4% provided academic and industrial experiences at the same time.

4.2 Techniques for software requirements elicitation

By answering the two research questions, we aim to obtain a broad picture of what the literature has reported in relation to the elicitation techniques and their effectiveness. With this aim in mind, we have collected information on which mature techniques are currently used for eliciting software requirements (RQ1) and which mature techniques improve the elicitation effectiveness (RQ2).

4.2.1 RQ1-mature techniques currently used for eliciting software requirements: About 109 studies were identified to answer RQ1: Which mature techniques are currently used for eliciting software requirements? As a first step in responding to this question, we reviewed studies published during 1993–2015 in order to identify the elicitation techniques that according to Christel and Kang [4] and Jiang *et al.* [30] are categorised as mature. Following these definitions, we found that interviews, workshops, focus groups, joint application development (JAD), quality function deployment, ethnography, scenarios, prototyping, protocol analysis, card sorting, ontologies, modelling, I*, goal-based approach, use cases, repertory grids, user stories, mind mapping, and group storytelling are mature techniques. Thus, a searching period from 2005 to 2015 (see Section 3.1) was established to identify within the SLR which of these techniques are currently used. Research by Nuseibeh and Easterbrook [35] have proposed a framework to group the elicitation techniques into six categories: traditional, group, prototyping, models, cognitive, and contextual; while research by Hickey and Davis [26] classified them into collaborative sessions, interviews, team building, ethnography, issues list, models, questionnaires, data gathering from existing systems, requirements categorisation, conflict awareness and resolution, prototyping, role playing, formal methods, and extreme programming. Moreover, Coulin [36] distinguishes among techniques, approaches, and tools available for RE, and provides a classification by using the Nuseibeh and Easterbrook framework. Thus, the elicitation techniques were categorised into traditional, cognitive, group, and contextual techniques; the approaches were categorised into modelling, combinational, collaborative, methodological, and social approaches; moreover, the available tools were classified into basic, method, cognitive, platform, and collaborative tools. Research by Tiwari *et al.* [37], Sharma and Pandey [38], Arif and Sarwar [39] classify the techniques into traditional, cognitive, contextual, and collaborative. Furthermore, Zhang [28], Serna [40], and Al Mrayat *et al.* [41] classify the techniques by the nature of communication. Finally, Gunda [42] classify them into traditional and modern, and Kausar *et al.* [43] provide an alternative classification with basic and advanced categories. From the consensus on the previous research (i.e. [26, 37–39]), and taking into account the Nuseibeh and Easterbrook categorisation due to its wide and logical coverage on elicitation techniques for evaluation and comparing purposes [36], we have classified the collected studies as follows:

- *Traditional techniques*: These techniques were the first used for requirements elicitation as software engineering has become more prominent. This category includes a broad class of techniques for the elicitation of generic data in order to determine and identify the wishes and needs of the stakeholders and the system limitations. In this context, we found a total of 38 studies for this category as follows: 30 for interviews, 6 for surveys, 1 for task analysis, and 1 for questionnaires (see Table 4).
- *Collaborative techniques*: These techniques aim to negotiate and promote agreements among stakeholders while exploiting the team dynamic. Thus, they are essential if there are several types of stakeholders or if three or more stakeholders carry out work in order to obtain the system's ideas and specifications. Moreover, the techniques of this category are used to select and prioritise the requirements within the elicitation process and provide a guide to discover basic concepts and improve the generic knowledge of the application domain. In summary, we found a total of 13 studies for this category as follows: five for focus groups, three for workshops, and five for brainstorming (see Table 5).
- *Prototyping techniques*: A prototype is a simplified version of the software (e.g. from sketches on pieces of paper to beta versions of software products). These are used when there is a high uncertainty with regard to requirements with the aim of obtaining a clear idea of the software performance in real life through obtaining detailed information about the system and promoting feedback among stakeholders. Similarly, Coulin [36] classifies prototyping as a contextual technique and Sharma and Pandey [38] and Arif and Sarwar [39] as a collaborative one. We found a total of four studies for this category (see Table 6).
- *Modelling techniques*: These techniques provide a specific model of the type of information that will be elicited, and they are used to lead the elicitation process and to obtain a better understanding of the stakeholders' needs, the context, and the project. This category involves techniques that use models such as scenarios, techniques based on goals and objectives (e.g. knowledge acquisition in automated specification (KAOS) and I*), business process modelling, use cases, and other techniques (e.g. data flow diagrams, state machine diagrams, and unified modeling language (UML) diagrams). We found a total of 29 studies as follows: 10 for scenarios, 11 for goal-based approaches, 2 for business process, 3 for use cases, and 3 for other techniques (see Table 7).
- *Cognitive techniques*: These techniques are based on methodologies or multidisciplinary approaches and include the set of tools that was originally created for knowledge acquisition in knowledge-based systems. Thus, this category of techniques aims to elicit requirements by representing and structuring the stakeholders' knowledge in terms of how they analyse a problem and its solution [35]. Table 8 shows that the most used techniques are ontologies, followed by card sorting and repertory grid. Ontologies are specifications of a conceptualisation (i.e. formal description of objects, their

Table 4 Studies related to traditional techniques

Technique	Studies references	Frequency
interviews	[44–73]	30
surveys	[74–79]	6
task analysis	[80]	1
questionnaires	[81]	1

Table 5 Studies related to collaborative techniques

Technique	Studies references	Frequency
focus groups	[82–86]	5
workshops	[87–89]	3
brainstorming	[90–94]	5

Table 6 Studies related to prototyping technique

Technique	Studies references	Frequency
prototyping	[95–98]	4

Table 7 Studies related to modelling techniques

Technique	Studies references	Frequency
scenarios	[99–108]	10
goal-based approaches	[39, 109–118]	11
business process models	[119, 120]	2
use cases	[121–123]	3
other techniques	[124–126]	3

properties, relations, limitations, and behaviours) in the certain domain [137, 138].

- *Contextual techniques*: These techniques are a combination of unstructured interviews and prototyping with concepts or ideas about the work environment. The aim of these techniques is to collect exhaustive data about the stakeholders, their processes, models, and workflows, the environment or another relevant area related to their work in order to obtain a detailed understanding of the requirements. This category is focused on directly obtaining requirements from the context (specific environment in the real world) due to its relevance in helping to understand social and organisational behaviours. These techniques are more commonly used in the usability field. We found a total of five studies that include techniques such as ethnography and ethnomethodology (see Table 9).
- *Agile techniques*: According to Hickey and Davis [26] and Coulin [36] user stories, mind mapping, and group storytelling are a methodological approach integrating agile techniques to a standard set of tasks to perform the requirements elicitation. Thus, Table 10 shows the studies found in relation to agile techniques.

A relevant aspect that is worth highlighting is that in 24 of the 109 studies (~22%) more than one requirements elicitation technique was used [44–46, 48, 51, 52, 56, 59, 61, 69, 70, 77, 79, 87, 94, 99, 104–106, 112, 120, 132, 136, 153].

Furthermore, from these findings, we can state that it is recommended that a software development project uses more than one technique for eliciting the software requirements. Moreover, taking into account the number of studies analysed, some techniques are no longer used in requirements elicitation (e.g. card sorting and repertory grid) which may in part be due to the increased use of others such as ontologies, collaborative techniques, and agile techniques that have been developed due to new communications channels or development methodologies.

4.2.2 RQ2-mature techniques that improve the elicitation effectiveness: About 31 studies were identified to answer RQ2: Which mature techniques improve the elicitation effectiveness? Unfortunately, most practising requirements engineers do not have the necessary insight to make an informed decision in selecting an adequate elicitation technique (‘analyst maturity’), and therefore rely on one of the first three reasons mentioned in [26] (i.e. it is the only technique that the analyst knows, it is the analyst's preferred technique for all situations, the analyst is following some explicit methodology, and that methodology prescribes a particular technique at the current time). However, according to the authors in [60, 144, 154–163] the aspects that the analyst must take into account for measuring the effectiveness of an elicitation technique are: software context, quality of the obtained requirements, amount of information elicited, indicator of user satisfaction, the number of defects in requirements, number of correct requirements, level of requirements completeness, level of requirements accuracy, the requirements volatility grade, and the level of agreement among stakeholders. Therefore, with the aim of answering this question, we first evaluated these aspects by analysing the empirical evaluation of the studies identified. From 21 mature techniques identified by RQ1, a set of 11 mature techniques showed effectiveness for the period 1993–2015, and the following findings were found:

Table 8 Studies related to cognitive techniques

Technique	Studies references	Frequency
ontology	[127–134]	8
card sorting	[135]	1
repertory grid	[136]	1

Table 9 Studies related to contextual techniques

Technique	Studies references	Frequency
ethnography	[139–142]	4
ethnomethodology	[143]	1

Table 10 Studies related to agile techniques

Technique	Studies references	Frequency
mind mapping	[144]	1
user stories	[145–152]	8
group storytelling	[153]	1

- The interviews were considered effective in either global software development (GSD) or traditional environments because these enable analysts to obtain more detailed information depending on the quality of the formulated questions [161, 164]. Additionally, researches by the authors in [154, 158, 164] recommend that the interviews be used as a primary technique because when combined with others the quality of the requirements will be increased (e.g. questionnaires, surveys, and brainstorming). Similarly, research by Daud and Bakar [165] compare ethnography and interview techniques. The result shows that interviews give more detailed work processes, while ethnography helps beginners to better understand the work processes.
- According to the authors in [102, 158, 166–168], when using the prototyping technique, the requirements engineer can obtain an early representation of the final product and, consequently, the customers are more satisfied. Also, prototyping is considered effective as a primary technique on distributed environments.
- As stated by the authors in [65, 168–173], the scenarios were considered as an effective technique due to their advantage of replacing the prototyping if the latter is costly or if the requirements are difficult to elicit. Besides, the scenarios can work well in traditional software development environments, GSD environments, and software agile development. Moreover, the scenarios are frequently used as a primary technique because they are more effective, when it is combined with prototyping, in preventing defects in the elicitation of complete, correct, and precise requirements.
- Research by the authors in [101, 156, 162, 174] stated the use cases and the misuse cases could improve the efficiency of the requirements elicitation because these enable requirements

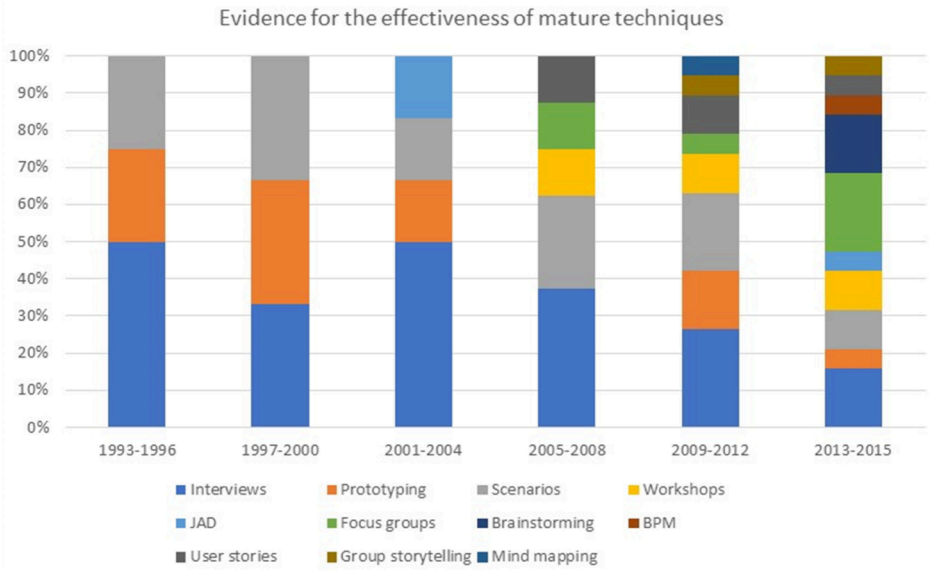

Fig. 2 *Timeline to represent the results for the effectiveness of mature techniques*

engineers to easily obtain security requirements. The misuse cases are a variant of the use cases and they are normally used to represent undesirable behaviours of software in order to elicit security requirements [162]. Additionally, use cases are an effective technique if they are used as a secondary technique.

- According to the authors in [161, 175–177], the workshops were considered effective because these help stakeholders to negotiate and collaborate in an effective way.
- Duggan and Thachenkary [157] affirmed that JAD is an effective technique for eliciting quality requirements. JAD is often used with rapid AD, an iterative and incremental approach for improving the quality and speed of a system design by supporting it with structured methods and computer aided software engineering (CASE) tools.
- Researches by the authors in [82, 84–86, 164] state that the focus group technique is effective because it promotes the discussion among stakeholder with the aim of formalising the requirements.
- Niknafs and Berry [93] and Konaté *et al.* [94] consider that brainstorming is an effective technique for eliciting needs by producing, voting, organising, and reviewing in a collaborative way all the ideas.
- Ordóñez *et al.* [152] show the effectiveness of the business process models compared with user stories in software agile development. The results indicate a higher effectiveness for models as a primary technique because these enable analysts to clearly specify the stakeholders' needs and business objectives.
- Isabirye and Flowerday [164] propose to use the user stories as a primary technique because the user stories take advantage of the usual mode of communication among stakeholders in order to obtain a complete understanding of the problem and its context (e.g. prospective users, business processes, socio-political structures) instead of technical details. On the other hand, Read and Briggs [148] present diverse formats to represent the user stories through different design stages in order to easily validate the consistency and completeness of requirements.
- Pitula and Radhakrishnan [159] state that storytelling is effective when stakeholders express their concerns and needs through user stories in the group (regardless of their literacy level, language, or social class). Moreover, according to Derrick *et al.* [153], the user story in groups generates more complete requirements. Another advantage is that one user can be verified and expanded by another user since the knowledge of one user helps to activate the knowledge of another group member, evaluate another's information, and ask for clarification.
- Finally, the mind mapping was considered effective by Mahmud and Veneziano [144] when they evaluated the effectiveness of this technique in SCRUM and concluded that mind maps are effective in increasing the quality of product backlogs.

Fig. 2 depicts a timeline to represent the collected evidence about the effectiveness of mature techniques for requirements elicitation.

As can be seen, interviews, prototyping, and scenarios were the most effective techniques used in the 1990s. However, with the passing of time, analysts have to take into account which characteristics make each technique effective (e.g. elicit complete information; identify and clarify ambiguities; reduce time of elicitation and subsequent stages of the RE; obtain and understand the knowledge of the domain; promote participation, collaboration, and feedback among the stakeholders; the ability to handle volatile requirements) [178]. Therefore, as a second step, we identified which characteristics make these 11 mature techniques effective (see Table 11).

Additionally, during the period 2013–2015, analysts were using a combination of techniques and iterative approaches in order to improve the requirements elicitation process and, consequently, increase its maturity. Furthermore, all the analysed studies argue that it is important to consider the experience of the requirements engineer when choosing the elicitation technique, something which requires good communication within the elicitation process.

Finally, with the aim of improving the reliability of the obtained results, we provide a comparison over six topics common with the SLRs described as related work:

- *Search field*: As in our SLR, Davis *et al.* [14], Dieste *et al.* [15], and Svensson *et al.* [16] focused their efforts on the software engineering field. Unlike Dieste and Juristo [17], who also included studies related to elicitation techniques out of this field, our research is focused to collect and analyse evidence of mature techniques on the software development context.
- *Elicitation techniques*: Our SLR has included all the elicitation techniques covering the maturity criterion defined by Christel and Kang [4]. Unlike Dieste and Juristo [17], who have only considered individual elicitation techniques (e.g. interviews, questionnaires, prototyping, and sorting techniques). That is to say, this SLR did not take into account group elicitation techniques such as JAD or brainstorming. Moreover, Dieste *et al.* [15] only considered techniques as interviews, protocol analysis, sorting, and laddering techniques.
- *Electronic databases*: Our SLR used six research databases: ACM Digital Library, IEEE Xplore, Springer Verlag, ScienceDirect, Google Scholar, Metapress, and Wiley InterScience, while [14, 15] used Scopus, IEEE Xplore, and ACM Digital Library. Furthermore, as [15] is an update of [14], this SLR added only Google Scholar to the used databases.

- *Research questions*: Our SLR has established two research questions focused on classifying the mature elicitation techniques, while [14, 15] focused their efforts on identifying which elicitation technique was most efficient in a particular setting. Moreover, Svensson *et al.* [16] established two research questions in order to identify the current situation of empirical investigations on quality requirements in relation to elicitation, prioritisation, cost estimation, dependencies, and metrics, and to identify the empirical research methods that had been used to evaluate quality requirements. Finally, in [17], a research question was established to identify the most effective elicitation technique.
- *Search string*: Derived from the previous research questions, it is obvious that all the SLRs have constructed different search strings in order to answer them.
- *Bibliography*: The searches in databases enabled us to obtain 270 references for our SLR, and led us to establish a final list of 140 studies by applying the inclusion and exclusion criteria, whereas the bibliographic database search in [14] identified 74 potentially relevant publications, and, after a bibliographic review, another 484 potentially relevant publications were identified, yielding a total of 564 publications that were thoroughly reviewed. However, the inclusion criteria led to the selection of 26 relevant empirical studies. Similarly, the bibliographic database search in [15] identified 43 potentially relevant publications, 60 empirical results, and 23 evidences. Nevertheless, in the end, only 9 new publications were taken into account, plus 26 from the previous SLR [14]. Moreover, in [16] a database and manual search identified 1560 studies, of which 18 were found to be empirical research studies of high quality. Finally, a total of 30 empirical studies from 564 candidate publications were considered in [17].

5 Other contributions

Additionally, 12 studies that were considered as false positives identify some factors that may be taken into account in obtaining

Table 11 Characteristics of mature elicitation techniques

Elicitation technique	Characteristics influencing the technique's effectiveness	Referenced studies	Frequency (number of studies)
interviews	• effective for eliciting relevant aspects from the stakeholders' needs and understanding problems in existing systems • effective for automation processes and innovation • able to recognise errors or clarify misunderstandings in requirements, through recapitulation and feedback • able to identify facts and opinions from stakeholders • useful to get a general view of the requirements • useful for discovering basic aspects of the context of providing a better understanding of the problem and a holistic perspective of the system • effective in quickly obtaining complete information (structured knowledge, detailed requirements), clarify ambiguities, and process improvement	[53, 60, 66, 73, 154, 156, 158, 160, 164, 172, 179–185]	17
prototyping	• efficient in obtaining a graphical and functional representation of the requirements • easy to combine with scenarios to graphically describe the users' tasks • able to combine diverse communication channels in order to achieve an intensive bidirectional communication, and efficient feedback and collaboration among stakeholders • effective in understanding the interactions with the system and capturing sufficient details of the graphical user interface • able to complement, clarify, and understand the requirements • effective for eliciting new requirements when it is combined with ethnography • effective in capturing accepted issues and the anomalous status of knowledge issues, as well as detailed information (i.e. rapid prototyping) • effective in reducing the elicitation time (i.e. evolutionary prototypes)	[102, 103, 158, 166–168, 185]	7
scenarios	• efficient in analysing the interaction between the software and user, and reducing discrepancies and ambiguities in the task's data flow by combining diverse communications channels • effective for the requirements refinement • a variant of scenarios, the scenario analysis, can be combined with structured methods to provide a clear feedback to analysts	[101, 105, 158, 164, 168–173, 185]	11
workshops	• useful because they consider all the needs of multiple stakeholders • effective for providing a complete set of diverse types of requirements and eliciting requirements from big and complex systems • useful for conflict resolution among stakeholders • effective for improving the understanding of stakeholders' needs and application domain through bidirectional communication • effective for structuring, prioritising, and managing the requirements • useful for managing the stakeholders' expectations	[161, 175–177, 185]	5
JAD	• useful for conflict resolution among stakeholders and for facilitating quick decision making • effective for early requirements elicitation through direct communication with stakeholders • effective for developing scientific and complex systems • useful for eliciting quality requirements and volatile requirements in the first iteration • effective for understanding social issues in order to obtain knowledge from the domain and obtain non-functional requirements	[157, 185]	2

focus groups	•	effective for conflict resolution within a group and its subsequent monitoring	[82, 84–86, 164, 185]	6
	•	effective for promoting a collaborative environment		
	•	effective in identifying the user and system expectations, as well as the relevant aspects of them		
brainstorming	•	effective in eliciting domain entities of a high level and for questioning assumptions that have been considered with limited approaches	[93, 94, 185]	3
	•	useful for generating a variety of ideas and system expectations (i.e. requirements)		
	•	effective for collecting opinions from all stakeholders		
business process models	•	useful for helping stakeholders to analyse their processes and tasks, and for solving the conflicts among them	[152]	1
	•	effective in improving the bidirectional communication between analyst and stakeholders		
	•	able to provide a basis for greater understanding, interpretation, and validation of the elicited requirements. At the same time, this technique helps analysts to eliminate requirements discrepancies and ambiguities		
	•	able to reduce the time for requirements validation and subsequent stages of the RE		
	•	effective in clearly establishing the requirements by better representing the process sequence		
	•	effective in eliciting a higher number of requirements		
user stories	•	easily adaptable to volatile requirements	[148, 152, 159, 164]	4
	•	effective in understanding general requirements and identifying ambiguous requirements		
	•	effective in improving the collaboration and feedback among stakeholders and the development team		
	•	able to reduce the time and cost of the elicitation stage		
	•	highly collaborative due to face-to-face communication		
group storytelling	•	effective in identifying ambiguous requirements	[153, 159]	2
	•	effective in improving the collaboration and feedback among stakeholders		
	•	effective for conflict resolution among stakeholders and obtaining clear requirements		
mind mapping	•	effective in increasing the quality of requirements	[144]	1
	•	effective in working the way people tend to think: in a non-linear fashion		
	•	effective in organising and representing information within a radial hierarchy		
	•	effective for obtaining complete information from the requirements		

an effective performance of the elicitation techniques [27, 28, 37, 40–43, 186–190]. These factors can be summarised as follows: project characteristics (e.g. type, status, and size), constraints (e.g. budget, resources, and schedule), level of correctness of functional requirements, quality concern of non-functional requirements, types of requirements, purpose and properties of requirements, level of abstraction of requirements, requirements sources, requirements obstacles, uncertainty level, type of information of knowledge that will be obtained, information resources, internal filter of knowledge, observable phenomenon, acquisition context, interdependencies among methods, application domain characteristics, social environment, type of communication among stakeholders, characteristics of the development team, stakeholders' characteristics (e.g. aim, number, involvement level, type or class, and type of end user), user involvement, requirements engineer characteristics (e.g. skills and experience), number of stakeholders, and elicitation type (direct or indirect). In summary, the use of the correct technique depends on diverse factors that make it appropriate for a situation, condition, or specific circumstance.

Furthermore, Table 12 shows that from these 12 studies, 8 studies identify the specific conditions for obtaining a better performance from 10 elicitation techniques. In addition to these studies, we have taken into account the research by Beg *et al.* [67], as it recommends using JAD and workshops if the stakeholders demonstrate specific characteristics and behaviours.

6 Threats to validity

The publications biasness and inaccurate extraction of data were considered to be the major threats affecting our SLR, each detailed below:

- *Searches*: The studies were chosen based on the search strategy described in Section 3.4, which include selection criteria and quality criteria. The terms corresponding or relating to the specified research questions were used to detect relevant studies that were used in this review. Nevertheless, there is still the possibility of missing important studies because not all studies can be extracted using the terms related to the research questions in their titles, abstracts, or keywords. However, since we extend our searches to include papers cited in the included papers, as well as key conferences, individual journals, and key authors, we are confident that the vast majorities of key papers have been included. Furthermore, to minimise the threat associated to the search for empirical studies using bibliographical references, or inaccurate extraction of data, all the selected studies were re-evaluated to identify the true positives, a situation where the title of a study could mean relevance, but the contents do not contain answers to any of the research questions.
- *Data synthesis*: It is possible that we have missed studies which should have been included in the set of 140 from which we extracted data. Some studies may have satisfied our assessment criteria, but either failed to report what they did or did not report it in sufficient detail for us to be confident that they should pass the criteria. Similarly, we may have missed the reporting of a detail and a paper that should have passed a criterion may have in fact not done so. However, these risks were mitigated by our two validation exercises to assess every study.
- *The inaccuracy of extracted data*: With the aim of reducing the inaccuracy of extracted data, we have carried out an independent valuation using the questions shown in Table 2 on the selected studies. Additionally, we later engaged in an inter-rater agreement to solve the discrepancies, as well as obtain similarities in the ordering of ratings executed, and an independent evaluation conducted by primary researchers and the independent expert.

7 Conclusions and future work

According to the CHAOS report from the Standish Group, one of the main reasons software projects fail can be found in the requirements stage [8]. A software product can fulfil the specified requirements if the necessary resources are provided for the whole RE process. Within this process, the requirements elicitation is a crucial stage where what will be developed is determined. Thus, it is important to identify the stakeholders and their needs instead of

Table 12 Identified conditions for obtaining better results from the elicitation techniques

Elicitation technique	Recommended conditions	Referenced studies	Frequency (number of studies)
interviews	• expert stakeholders in the domain and available time. They are also accessible, expressive, and an expert interviewer supports them • the requirements engineer should have an open mind and patience to listen to stakeholders	[42, 187]	2
questionnaires and surveys	• diverse stakeholders are involved	[187]	1
ethnography and ethnomethodology	• the aim is the replacement of a system • there are no schedule constraints. • the user is highly expressive	[43]	1
scenarios	• limited schedule and low budget	[190]	1
prototyping	• stakeholders are unable to express their needs • complex systems development • the development of a new product or the improvement of an existing one • the evolutionary prototypes can be used when the requirements have been well understood, as the stakeholders can provide more functionality when one that was previously identified is analysed	[42, 187, 191]	3
workshops, JAD	• multiple stakeholders that need collaboration to obtain a complete picture of the requirements • stakeholders that are geographically dispersed and need more productive meetings • expressive stakeholders • the stakeholders do not know the requirements or they provide these incorrectly • development of large and complex systems (workshops) or distributed and critical systems (JAD workshops)	[26, 37, 67, 187, 190]	5
story boarding	• limited schedule and low budget • user's close involvement with immediate feedback	[37]	1
laddering	• stakeholders without previous experience of the problem that must be solved	[17]	1

their wishes. Furthermore, in the elicitation stage, the context and application domain are identified in order to obtain high-quality requirements, by using elicitation techniques that help requirements engineers to find a balance and negotiate the stakeholders' interests.

This paper has presented an SLR to investigate the mature techniques most used by the elicitation process, and carry out an analysis on those that have been proven effective, highlighting the particular characteristics that make them an objective technique (elicit complete information; identify, and clarify ambiguities; reduce time of elicitation and subsequent stages of the RE; obtain and understand the knowledge of the domain; promote participation, collaboration, and feedback among the stakeholders; to be able to handle volatile requirements).

Thus, the findings show that the most used techniques, within the group of traditional techniques, are: interviews, scenarios, and questionnaires. With regard to the group techniques, workshops stand out among all techniques, while the goal-based approach is highlighted from the modelling techniques category. Moreover, ontologies are the most used technique from the cognitive techniques and ethnography and prototyping are highlighted within the contextual category.

Similarly, to measure the effectiveness of the elicitation techniques, it is necessary to analyse diverse factors [e.g. environment or context where software will be developed, elicitation context (traditional or distributed), problem domain, type of project, type of knowledge that will be obtained (explicit or tacit), the stakeholders' characteristics (level of expertise of the requirements engineer, stakeholder role, type of source, knowledge, and skills), available resources (schedule and budget), and more]. Taking into account these factors and considering the studies analysed, the techniques that have demonstrated their effectiveness are: interviews, scenarios, workshops, focus groups, agile methodologies, brainstorming, modelling, prototyping, and questionnaires.

Although there is no evidence that supports the comparison among the effectiveness of all elicitation techniques in same conditions (i.e. requirements engineer knowledge, domain context etc.), it is important to mention that each technique has particular advantages that make it more effective in specific situations (e.g. use cases are used to elicit requirements when it is necessary to describe the interaction flow between the system and the stakeholders). Furthermore, the effectiveness of elicitation techniques is reflected in the quality of the obtained requirements. Therefore, it is important that the requirements engineer chooses those techniques that are best suited to the project that will be developed and the problem that will be solved, in order to create a quality list of wishes and needs (i.e. correct, complete, consistent, unambiguous, verifiable etc.) and thus contribute to the success of the software project. It is true that a quality list does not ensure the project's success; however, a poor-quality list will ensure its failure.

Finally, future work will mainly cover the development of a new SLR on the metrics used in the requirements elicitation stage in such a way that enables us to analyse what aspects are covered by those metrics and, therefore, propose some others to obtain quantitative data about the effectiveness of the requirements elicitation techniques, as well as the whole elicitation process (i.e. covering all the tasks and activities performed in this stage). Additionally, after considering more complete results, we will design guidelines to use the elicitation techniques correctly taking into account the conditions where they work better as well as recommended combinations of techniques that best fit a specific project.

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