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A Discussion of the Impact of Judgmental Heuristics on Elicitation during Requirements Engineering

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***Abstract*—A stakeholder decides which information to share during requirements elicitation. These decisions are made under uncertainty: stakeholders may not have precise, concrete, and complete information about their own expectations from, or about the environment of the system-to-be, they may misunderstand information which a requirements engineer gives them, and they may not have perfect knowledge about the various opportunities that the current technology may offer. Stakeholders' decision-making is therefore likely to involve the use of heuristics. Understanding if stakeholders do indeed use heuristics during requirements elicitation, and if so, then which ones, should help understand requirements elicitation better, and design methods which can stimulate positive heuristics (those which help elicit relevant requirements) and mitigate negative ones. This paper defines what an elicitation heuristic may be, and proposes a set of research questions under the form of a matrix for the theoretical and empirical study of elicitation heuristics.**

***Keywords*—Requirements, Elicitation, Judgmental Heuristics**

I. Introduction

Requirements elicitation (or simply *elicitation*) designates activities performed to collect information about the requirements of a system-to-be or the environment in which that system will run. Elicitation produces information that is used in other Requirements Engineering (RE) activities, the aim of which is to produce a requirements specification, which, in turn, will inform the engineering and development of the system. Elicitation typically involves two parties: the stakeholders and the requirements engineers. The latter elicit information from the former. This elicitation process involves decision-making; engineers decide what to ask or how to otherwise stimulate the stakeholders to provide information, stakeholders choose which information to provide to engineers. Many factors influence stakeholders' decisions to share or not information. Elsewhere, we studied how the elicitation context influences the information that a stakeholder chooses to provide [1]. The focus in this paper is on the role that *uncertainty may have on stakeholders' decision-making during elicitation*. Stakeholders may have various backgrounds, experience, expectations, and expertise. They may be concerned or focus only on some aspects of a system, and ignore others. They can thus hardly predict with certainty how the system will influence their environment and activities. That is, stakeholders make decisions under uncertainty, when choosing the information to give during elicitation.

Decisions that people make under uncertainty are called judgments [2], i.e., stakeholders make judgments during elicitation. *Judgments are influenced by heuristics.* This is the case in general, regardless of what the decisions are about. In their seminal paper on choices under uncertainty, Tversky and Kahneman suggested that decision-makers use heuristics to formulate beliefs to support judgments [2]. Heuristics can be seen as strategies used by decision-makers to "reduce the complex tasks of assessing probabilities [of an event] and predicting values to simpler judgmental operations" [2]. There is considerable research on the identification of biases related to judgmental heuristics. It suggests that using heuristics may lead to non-optimal decisions [3]. Another line of work sees heuristics as mechanisms whose deficiencies are compensated by advantages. This is more recent research, which suggests that a heuristic is not good or bad in itself, but is more or less efficient depending on the context of the decision [4].

If heuristics influence judgments in general, then they also influence stakeholders' and engineers' judgments during elicitation. The premise of this paper is that if these impacts are understood better, then that understanding can help engineers during elicitation. For example, a heuristic might work as follows: a stakeholder will not, or is less likely to argue against a requirement which was given by an influential stakeholder. Another heuristic may be that the stakeholder will not argue against a requirement which was already approved by the majority of the stakeholders. Elicitation can be adjusted to minimise the influence of such heuristics, or to benefit from these heuristics. For the first heuristic, if the engineer's aim is to get a requirements approved quickly, she may inform other stakeholders about who gave it. If the aim is, instead, to find out if some stakeholders oppose the requirement, then it may be more appropriate to hide who gave that requirement. This gives the following central research question: *Do judgmental heuristics influence elicitation, and if yes, then how?*

The question above is hard. There is no known complete set of judgmental heuristics in existing research on decision-making in general. To the best of our knowledge, there is no research on the role of the known ones specifically in elicitation. There are no theoretical discussions which relate judgmental heuristics to elicitation, and there are no tested instruments for empirical research into the influence of judgmental heuristics on elicitation. The research question above sets a long term goal, and this paper suggests a list of research questions towards one aspect of that goal. Namely, this paper proposes a research question matrix towards the following research question:

> *Is there a relationship between properties of elicited information and judgmental heuristics applied by stakeholders when giving that information?*

In other words, does the use of judgmental heuristics during elicitation influence the properties of the information obtained during elicitation? To clarify this research question, consider the following example. In elicitation, it is common to categorise some information that stakeholders gave as being about requirements, while other information is about the environment of the future system. One of the judgmental heuristics discussed in this paper says that, if one needs to give information, then among alternative information she can give, she is more likely to give that which is easier than others to recall from memory. In this specific case, the research question becomes: Is information about requirements easier to recall than information about domain knowledge? We identify many such specific research questions, and suggest how to obtain empirical data to answer them. The questions are based on two sets of classification dimensions: (i) one set is based on prior RE research, and gives rules for the classification of elicited information, called **statements** below. These dimensions are called **RE classification dimensions**, (ii) the other set of classification dimensions are called **Heuristics classification dimensions**. Each classification dimension is based on one or several judgmental heuristics identified in existing research.

II. Heuristics Classification Dimensions

We first identify existing judgmental heuristics and discuss their potential role in elicitation. We take judgmental heuristics which are likely to be used by managers and other corporate decision makers [4]. We then discuss if, why and how these judgmental heuristics might be used by stakeholders to decide which statements to share during elicitation. The elicitation heuristics suggest the Elicitation classification dimensions for statements. The classification dimensions are not exhaustive, as they are based on a subset of judgmental heuristics which are currently known in research, and research on judgmental heuristics is still ongoing, with potentially new heuristics to be formalized in the future.

A. Recognition Dimension: Accessible or Distant

This first classification dimension is suggested by the Recognition, Fluency and Take-the-first judgmental heuristics [4]. These heuristics are used in recognition-based decision-making. Namely, when a decision-maker has to select one among a set of alternative statements, she will pick the one she recalls the more easily and rapidly from memory. On the contrary, alternative statements which are difficult to access will tend to be overlooked, regardless of how relevant they may be in elicitation. This suggests two categories of statements. *Accessible statements*, which can be retrieved easily and/or rapidly from memory or which refer to something that is easily and/or rapidly retrievable from memory and *Distant statements*, which are distant and difficult to retrieve from memory, or which refer to something that is hardly accessible in memory. An illustration of these heuristics is the case of a stakeholder who has to select one refinement of a business goal, among two different ones. The stakeholder may pick the refinement of the goal that best fits with what comes the more rapidly to her mind. Typically, this will be the alternative she is more familiar with, that she encounters regularly, or that is not too complex and hence relatively easy to remember.

B. Rationale Dimension: Verified or Refuted

This classification dimension is inspired by the Take-the-best and One-clever-cue judgmental heuristics, and more generally by heuristics used in the case of one-reason decision making [4]. These heuristics work on the idea that an alternative statement is chosen as soon as it is observed that this statement satisfies one specific condition. This condition is used by the decision-maker either because it discriminates sufficiently among different possible alternatives (take-the-best heuristic) or because it is innate and the decision-maker does not want to use another (one-clever-cue heuristic). This suggests the following categories of statements. *Verified statements*, which are selected by stakeholders based on a single selection criterion, and *Denied statements*, which are rejected by stakeholders based on a single selection criterion. For illustration, take the case of a stakeholder who has to decide which of two conflicting requirements to keep. The stakeholder may decide to keep the requirement which requires less time to develop, and consider no other aspects of the two conflicting requirements such as the cost of development, the impact on other systems in the business, etc. This criterion is used by the stakeholder because, from the set of criteria she though of, time of development was the one that was the most discriminant one (take-the-best heuristic), or the one she always uses when she has to make such decision (one-clever-cue heuristic).

C. Tradeoff Dimension: Consensus or Disagreement

This classification dimension comes from the Tallying Heuristic, which implies to identify several criteria for comparison, and selecting the alternative which satisfies the best this set of criteria [4]. The decision maker will evaluate, for each possible alternative, the number of criteria that are met, and will select as a solution to her problem the alternative which scores best. This brings us to the definition of *Elected statements*, which are selected by stakeholders based on more than one selection criterion and *Dismissed statements*which are rejected by stakeholders based on more than one selection criterion. The illustration of this heuristic is similar to that for the Rationale dimension; to decide between two conflicting requirements, a stakeholder may consider three criteria - namely, development time and cost, and impact on the other systems - and select the alternative that matches most of these criteria. The difference here is that each statement is evaluated against each selection criterion, unlike in the Rationale dimension where only one selection criteria is used to evaluate the different alternatives. Although close in their way of working, the output may therefore significantly vary.

D. Resilience Dimension: Default or Exception

This classification dimension is derived from the so-called Default heuristic [4]. Roughly stated, this heuristic suggests that a decision-maker will typically select from a set of alternatives, the one that best reflects the standard way of doing something according to her experience. This brings us to the definition of the following statements; *Default statements*, which a stakeholder selects because they reflect her understanding of the world and *Exception statements* that a stakeholder rejects because they clash with her understanding of the world. An illustration of this heuristic is the case of a stakeholder who has to decide if the business rule “backup

business data every hour" is still applicable to the system-to-be. Perhaps the rule was initially adopted a decade ago, when there was no reliable cloud solution. It is unclear if this business rule is still relevant now. In order to decide about such problem, the stakeholder may resort to the default heuristic and consider that, by default of other indications that would contradict it, the business rule is still applicable. Doing so, the stakeholder decides to follow the standard procedure.

E. Imitation Dimension: Influencer, Majority, Minority

This last classification dimension is suggested by the Imitate-the-Successful and Imitate-the-majority heuristics [5]. With these heuristics, a decision-maker selects a solution from a set of alternatives if there are cues that others adopted that same solution. Successful or famous people will be considered in the case of Imitate-the-Successful heuristic. Large groups and majorities will be preferred when making use of the Imitate-the-Majority heuristic. This suggests the following statement categories. *Influencer statements* are statements which a stakeholder selects because they seem to convey the same information as statements given by individuals, who are perceived as influencers of widely-held opinions. *Majority statements* refers to statements which a stakeholder selects because they seem to reflect the opinions of the majority. *Minority statements* are statements which a stakeholder rejects because they seem to clash with statements of influencers and, or the majority. Say for instance that a stakeholder has to decide whether she will ask to have mobile access (on a smartphone or tablet) to the system-to-be. If the stakeholder is unsure about this decision, she may decide to look at the decision of other stakeholders. For example, she might follow her superior's choice, whichever it is. Alternatively, she might make the same decision as the majority of the stakeholders, even though she may not need mobile access. In both cases, she resorts to the so-called imitation heuristics.

III. RE Classification Dimensions

To identify RE classification dimensions, we review RE literature which suggested taxonomies of goals/requirements. We limit our review to dimensions which originate in some way from speech acts of stakeholders [6]. We do not take into account technical taxonomies which are specifically intended for engineers. The list of classification dimensions is not exhaustive, but provides ample material for the discussion. For illustration, consider the following statements. Assume that they are speech acts resulting from decisions made by stakeholders in a context of uncertainty and are therefore likely produced through judgmental heuristics. We want to discuss how these statements differ from each others.

- *S1*: Optical fiber cables are used to transfer data anywhere in the world in less than a second;
- *S2*: I wanted to access business data from my smartphone in no more than 10 seconds;
- *S3*: I'll use the app if it updates easily and no too slowly;
- *S4*: We used to know when our sales targets were achieved when the indicator turned blue or green;
- *S5*: I think it is critical to me that, in case of server breakdown, (i) a backup service is launched automatically or (ii) the IT service is immediately contacted and a warning email is sent to user.

A. Nature Dimension: Environment or System

This classification dimension is inspired by Zave and Jackson's distinction [7] between information related to the environment of a system (domain knowledge), information about what is expected from the system-to-be (requirements), and information about how the requirements will be satisfied by the system-to-be (specifications). This distinction leads us to distinguish between two kinds of elicitation statements. *Environment statements* focus on conditions and events in the environment which may influence the system-to-be, while *System statements* focus on conditions and events controlled by the system, and, or which the system may influence in the environment. In our running example, S1 is an environment statement, because it describes a condition of the environment in which the system will operate; the fact that optical fiber cables are used is not related to the system, but to the environment in which that system will operate. On the contrary, S2, S3, S4 and S5 are system statements, because they all somehow describe information about the system itself, and not about its context.

B. Type Dimension: Function or Quality

This classification dimension comes from the distinction made in RE literature between the so-called functional and non-functional requirements, or goals. The former type of requirements refer to a function, a service, that is expected from the system-to-be. The latter type of requirements are to be seen as constraints, or qualities, being set on how functions are delivered [8], [9]. The fact that a requirement is functional/nonfunctional has an important impact in terms of validation; functional requirements have clear-cut validation criteria, while conditions to validate the satisfaction of nonfunctional requirements are often hard to define. This validation distinction leads to a RE dimension of statements with two different level. *Functional statements* are about events and conditions whose occurrence and holding can be established without a doubt while *Quality statements* refer to events and conditions whose occurrence and holding can be evaluated in different ways, by different people. In our running example, S1, S2, S4 and S5 are functional statements: they describe things about the system or its environment which leave no room for interpretation; for example, it can be established without a doubt that there is optical fiber in the data center, or that an indicator is green or blue. On the contrary, statement S3 is typically a quality statement, since the adjectives easily and slow are likely to interpreted differently by different people.

C. Guidance Dimension: Problem or Solution

This classification dimension is due to the fact that stakeholders may guide the analyst in different ways during elicitation. Most of the time, we expect stakeholder to simply share things they expect from the system-to-be, and analysts to find the best way to satisfy that requirement. In other words, the stakeholder shares the requirements, while the analysts identifies the specifications of the system so as to satisfy these requirements [7]. Sometimes however, it may also happen that stakeholders share requirements together with some indications about how they expect them to be satisfied. This distinction brings us to a guidance dimension, with two types of statements. *Problem statements* are conditions and

events which are either undesirable, and need to be prevented, or are desirable, whereby the statements do not say how to, respectively, prevent or achieve these conditions and event. *Solution statements* are about how to prevent undesirable conditions and events and, or achieve desirable conditions and events. In our running example, S2 and S3 are problem statements because they describe behaviors with no indications about how it should be satisfied. On the other hand, S4 and S5 are solution statements, providing indications to engineers about how the requirement could be satisfied. S1 is a Problem statement about the environment: it describes a condition in the environment (i.e. information can be transferred anywhere in the world in less than a second) together with the way it is achieved (i.e. using optical fiber).

D. Structure Dimension: Atomic, OR, AND or Complex

This classification dimension is common sense and is inspired by the logical disjunction and conjunction mechanisms. More precisely, it starts from the observation that statements being shared by stakeholders are not always simple. Sometimes, requirements being shared may imply several clauses to be related to each other with some conjunctions and/or disjunctions. In RE, the structure of a requirements or a goal is usually handled through AND/OR relations [10]. This brings us to an RE dimension with four different types of statements. *Atomic statements* are about a single event or condition, *OR statements* combine two or more mutually exclusive events or conditions, *AND statements* combine two or more events or conditions, none of which are mutually exclusive and finally *Complex statements* where more than two events or conditions are combined, some of which are mutually exclusive. In our running example, S1 is an atomic statement because it describes one single condition. S3 is an AND statement because it involves two events which are not mutually exclusive. S4 is an OR statement because it refers to events which are mutually exclusive: the light bulb in a same lift cannot be blue and green at the same time. Finally, S5 is an example of complex statement, because it involves three events combined with both AND and OR.

E. Source Dimension: "I", "We" or Impersonal

This dimension is inspired by research on the impact of groups on the definition of requirements [11]. The underlying idea is that a requirement being suggested by a group is more likely to be of better quality and creativity than a requirement being suggested by some individuals alone [11]. This suggests that a statement can be shared either as the request of a single person, or as the result of some concertation between several individuals. As it may happen that a statement cannot be attributed to one person or group in particular (as the result of culture, popular knowledge, science, etc.), we also consider an impersonal source of statement. This leads us to a three-level RE dimension. *I statements* are statements which convey speaker's own beliefs, and with which the speaker does not convey that others hold these beliefs. *We statements* are statements which convey speaker's own beliefs, and with which the speaker conveys that these beliefs are held by others as well. Finally, *Impersonal statements* convey general knowledge, opinions or ideas which cannot be attached to one particular individual or group. In our running example, S2, S3 and S5 are examples of I statements; they are expressed as the result of an individual decision. S4 on the contrary is clearly expressed as the result of a mutual decision. Finally, S1 is about a condition that is not directly produced by the person who shares the statement, neither by a group of several stakeholders. It simply reflects a condition that is true and that cannot be associated with one person or group in particular, so that it is expressed in an impersonal way.

F. Time Dimension: Past, Present or Future

This dimension comes from the distinction that is sometimes made in RE between the requirements intended to maintain a condition and the requirements intended to achieve or cease to do something; for example, the patterns suggested in KAOS [12]. We believe this distinction also applies to statements, in a more generic form. We interpret "maintain" requirements as being statements about the present situation; something that is currently observed, and which may be expected to hold true in the future. On the contrary, we interpret "achieve" and "cease" requirements as statements about the future; that is, things that are not true in the present, but expected to be verified in the future. Although RE literature does not define a type of requirement about the past, we believe that some statements may be formulated about things that were true in the past, and that do not longer hold. This leads us to a three-level RE dimension. *Past statements* are about events and conditions which occurred/held in the past, and no longer do today. *Present statements* are about events and conditions occurring/holding at present. *Future statements* are about events and conditions expected to occur/hold in the future, and do not at present. In our running example, S2 and S4 are typical examples of statements formulated about the past, for which there is not certainty today. S1 and S5, on the other hand, are formulated to express current ideas or actions, which are happening nowadays. S3 is a statement about the future: it describes nothing about the present or past situation, but simply states something about what is expected to hold true in the future.

G. Mood Dimension: Descriptive or Prescriptive

This dimension is inspired by the distinction that is made in modeling between models that describe the state of a system or a domain, and the models that aim to describe what is expected from future system or domain. Such distinction is also common in RE; the i* modeling language for example can be used in a descriptive way, as a mean to describe an existing business, or in a prescriptive way, as a mean to describe what context should be achieved via the new system [13]. This brings us to the mood RE dimension, with *Descriptive statements* describing events and conditions independently of being desirable or not and *Prescriptive statements* describing desired events and conditions. In our running example, S3 and S5 are prescriptive statements because they clearly state that there are some needs, and that actions are expected in order to fulfill the needs. On the contrary, S1, S2 and S4 are descriptive statements; they describe things, with no clear indications about whether these things are desired. The purpose of these sentences is simply to provide information about the situation, as-is.

H. Background Dimension: Experience or Speculation

This last dimension is based on the idea that, in a context of uncertainty, stakeholders may be willing to express a degree of certainty about the statements they mention. In some cases, stakeholders may state that they "think" or "believe" a statement, and that they are not "sure" or "convinced" of the latter. One way to explain such difference between statements is the background being used by the stakeholders to produce the statements. Stakeholders may either justify their statements with some of their past experience, in which case they will appear to be relatively certain of the statements they share. On the contrary, they may resort to speculation, and share statements they are not certain of. We have found no research in RE about that concept of statements background, yet we believe it might be an interesting property to account for in the rest of this paper. *Experience statements* are statements supported by own experience, that is, events and conditions experienced in the past. *Speculative statements*, or the other hand, are not supported by own experience. In our running example, S1, S3 and S5 are speculative statements. It means that it seems, based on the statements, that the stakeholder who shared the statement has never experienced it. This is clearly not the case of S2 and S4, where the stakeholder clearly refers to some past experience as a way to support the statement.

IV. A Matrix of Possible New Elicitation Filters

We see research areas at each intersection of a RE dimension with a Heuristic dimension. In each of these research areas, there are several research hypotheses, which always take the same form; there is a correlation between one level of a RE dimension, and one level of a Heuristic dimension.

A. Feeding the Research Question Matrix

These research hypotheses are the 220 empty cells in Figure 1, and suggest new empirical questions to be investigated. It is not feasible to write down all the hypotheses suggested by the Matrix, yet we believe it is useful to state at least one of them explicitly. Consider **research Area 10**: "does the imitation elicitation heuristic influence in some way the chances of a statement to be a functional requirement (as opposed to non-functional requirements, i.e. quality)?". More precisely, does the fact that a statement is a majority, minority or influencer statement correlate with that same statement being a quality or a requirement? Our intuition here is that qualities have a larger granularity, so that the stakeholder will only communicate it to the analyst if she is certain a majority of stakeholders agrees on that quality, i.e., H_6 (sixth box in area 10): there is a significant correlation between majority and quality statements. A requirement on the other hand has a smaller granularity, which makes it easier for the stakeholder to communicate to the analyst despite the statement being a minority statement, i.e., H_2 (second box in area 10): there is a significant correlation between minority and requirement statements. Our intuition about the other intersections (H_1, H_3, H_5 and H_6) is that there should not be any significant correlation, which are other relevant hypotheses to validate.

B. Empirical Evaluation of the Matrix

The matrix suggests empirical study of correlations and relationships between the different dimensions. More precisely,

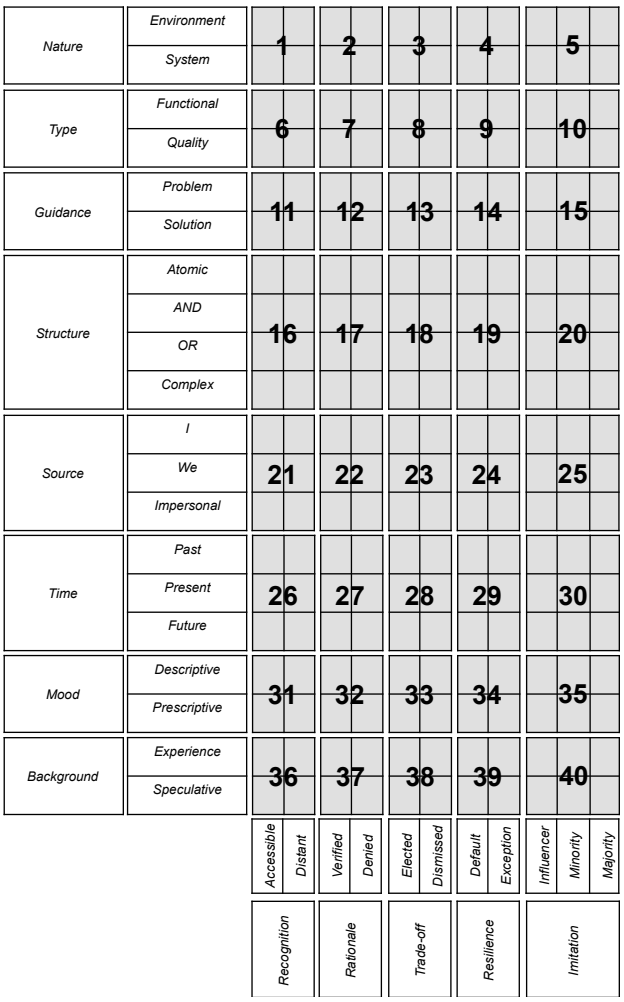

Fig. 1: Research Matrix of Potential Elicitation Filters Studies

we suggest research which estimates the frequency in each cell, or the correlation between two levels from different dimensions. Ultimately, this would result in a map of the risks and benefits of using some heuristics rather than others. For example, looking in the first column, one could select the top five values and the top five worst values. Doing so, we would identify the statements that are the more likely to be shared or overlooked by a stakeholder, using the Recognition heuristic. Such a tool can be used during elicitation to help analysts elicit more information. To obtain these values, specific empirical tools must be designed, so as to capture statements and classify them according to at least one heuristic dimension, and one or more RE-dimensions. These statements, once collected, could be summarized under the form of a contingency table like in Table I, and reported in the matrix. The letter N refers to a number of occurrence, and the ratio in Table I represent the relative frequencies inside a research area. As a way to confirm or reject the existence of an actual relationship between two dimensions, statistical tests based on chi-square test can be computed for each contingency table appearing in the matrix (research area), such as Table I. Additional statistical tools like the Pearson or Spearman correlation coefficient (depending on

TABLE I: A contingency table for the Imitation-Nature Area

	Majority	Influencer	Minority
Environment	N_{EMaj}/N	N_{EInf}/N	N_{EMin}/N
System	N_{SMaj}/N	N_{SInf}/N	N_{SMin}/N

the type of data being collected) can be used to study the importance and direction of the effects.

C. Positioning the Matrix

Most of the questions suggested by the Matrix remain somehow unanswered in the context of information elicitation. Yet, the importance of adopting a cognitive or decision-making approach to elicitation and RE in general is often recognized. In [14], RE is presented as a decision-making intensive activity during which it is critical to better understand how engineers and stakeholders reason and decide to treat information. A similar view is adopted in [15], [16], where it is claimed that RE engineers make use of various heuristics or stopping rules to determine the sufficiency or priority of information gathered during the elicitation of requirements. In [17], a set of stakeholders enablers and inhibitors is defined, which paths the way for future research on how heuristics influence elicitation. In [18], it is clearly highlighted that cognitive sciences may help RE community in better dealing with main issues related to elicitation. None of the previous papers however conduct actual empirical study, nor do they address specifically one or more of the questions suggested by our Matrix. In [19], it is claimed that most problems related to elicitation can be traced to human cognitive limits, so that better understanding those constraints and the strategies used by human to overcome them turns out to be a worthy endeavor for RE researchers. We found few papers dealing explicitly with the use of judgmental heuristics by stakeholders, the biases such heuristics lead to during elicitation of requirements, and the techniques which could be used to deal with such biases.

V. Conclusions

This paper suggests a set of research questions for theoretical and empirical research on the role of judgmental heuristics in requirements elicitation. It starts from the observation that, during elicitation, stakeholders make decisions under uncertainty. As a consequence, they may resort to judgmental heuristics to make decisions about which information to share with the analyst. Our focus in the paper is to explore the usage of such heuristics and how it connects with the outcome of elicitation. As a first step to answer that question, we suggest a research question matrix, which defines a list of research questions about the potential impact of heuristics on the identification of elicitation statements. The matrix is obtained from a combination of two different classifications of statements that stakeholders can provide during elicitation. The first classification, RE-oriented, identifies a list of dimensions which can be used by analysts in order to characterize and distinguish different statements. The second classification, heuristic-oriented, identifies a list of dimensions which can be used to explain why some specific statement was given by a stakeholder. By combining these two classifications, we obtain a list of 220 research questions, that we argue can be addressed theoretically - through, for example, the study of ecological rationality or judgmental biases in elicitation - or empirically - through the study of correlation. The long term objective of the matrix is to lead to new research on requirements elicitation.

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