Cognitive Factors in Inconsistency Management

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Abstract—Inconsistency is a major challenge in requirements engineering, commonly perceived as a problem that needs to be eliminated on sight. However, in practice maintaining consistency at all times is an intractable problem. Accordingly, recent paradigms for inconsistency management acknowledge that it is sometimes desirable to tolerate inconsistency, e.g. to allow distributed teamwork and prevent premature commitment to design decisions. However, a successful adoption of inconsistency management paradigms in industry depends highly on the human factor: intolerant attitudes of practitioners toward inconsistency may pose significant barriers to a wider acceptance of these paradigms. A thorough analysis of cognitive factors is a key to overcoming these barriers. This paper reports on our preliminary empirical findings highlighting existing perceptions and attitudes of practitioners toward inconsistency, and propose dimensions for their classification. Based on these results, we outline a general research program for exploring cognitive factors in inconsistency management.

Index Terms— Inconsistency management, human factors, IS development, method adoption.

I. INTRODUCTION

Handling inconsistencies is a key challenge in requirement engineering (RE). Inconsistency may occur, for example, when requirements or specifications contain conflicting or contradictory descriptions of the expected behavior of the system or of its domain. Such conflicting descriptions may come, for example, as a result of conflicting goals between different stakeholders, changes introduced during the evolution of the requirements, etc. [1].

Until recently, the common perception of inconsistencies in RE was as a problem that needs to be eliminated before further activities can take place. Over the last decades, however, a more tolerant approach towards inconsistency has evolved, e.g., [1][2][3][4][5][6][7][8].

In “Making inconsistency respectable in software development”, Nuseibeh et al. [9] argue: “Maintaining consistency at all times is counterproductive. In many cases, it may be desirable to tolerate or even encourage inconsistency to facilitate distributed teamwork and prevent premature commitment to design decisions.” Finkelstein [10] further advocates this paradigm shift, proposing that rather than removing inconsistency we need to manage it by “preserving inconsistency at the point where decisions are required and removing (or otherwise remedying) inconsistency prior to taking action. This requires a major change in the way we think.”

But changing the way we think is not always simple. It is commonly acknowledged that practitioners generally hold negative attitudes towards inconsistencies [1], which may pose significant barriers to a wider acceptance of inconsistency management paradigms in industry. A thorough, in-depth analysis of such attitudes, and cognitive factors from which they stem, is a key to overcoming these barriers. However, thus far, the discussion about inconsistency management in RE has focused more on methods and tools, giving less attention to the human factor. This ongoing research seeks to understand what are the cognitive factors affecting inconsistency related decision making and how effective inconsistency management can be achieved. This paper proposes a roadmap toward pinpointing and analyzing perceptions and attitudes RE practitioners hold regarding inconsistency and accordingly proposing means for facilitating wider acceptance of inconsistency management paradigms.

This paper reports on our exploratory empirical findings highlighting existing perceptions and attitudes towards inconsistency in RE. We further propose a research roadmap for exploring cognitive factors in inconsistency management. The obtained insights may help facilitate a wider acceptance of inconsistency management paradigms in industry, as well as serve as a basis for developing efficient methods and tools to support inconsistency related decision-making.

II. THE EMPirical STUDY

A. Method

Due to the exploratory, human-centered nature of our study, we took a qualitative research approach, which is preferred when aiming to study and understand complex socio-technical processes [11]. More specifically, we used the grounded theory methodology, which is appropriate in order to generate descriptive or explanatory theory: when using grounded theory methodology, no theories are pre-decided and there is no hypothesis to accept or reject; rather, relevant theories are investigated throughout the iterations of data collection and analysis [12]. Accordingly, data were iteratively collected and analyzed. Categories that emerged from the data were validated and refined throughout the data collection and analysis process.
Twenty participants were selected and interviewed in our study. Participants’ sampling was performed according to the theoretical sampling principles [13]. The sampling criteria we defined were as follows: A participant had to have an academic background in information systems, software engineering, or computer science, and professional experience in industry or in research in RE. In order to reflect variations within our data, we also aimed to achieve a diverse sample of participants, from different domains and with different roles and levels of experience. The roles included requirements analysts, software architects, and project managers. Their professional experience was 13 years on average, varying from three to 35 years.

The main tool of data collection was semi-structured in-depth interviews, which were conducted by the authors. The interview questions focused on the notion of inconsistency in the context of RE. We asked the interviewees to explain what inconsistency is and how it is manifested in RE, and requested their opinions and suggestions regarding handling inconsistencies. We further scrutinized their attitudes towards the different manifestations of inconsistency, as reflected by their expressed emotions and their proposed strategies for handling them.

Data analysis was done by the authors, according to the principles of the grounded theory analysis for generating descriptive or explanatory theory [13], resulting in the conceptual framework presented below. More specifically, data analysis included open, axial, and selective coding [14]. We used open coding for determining categories of perceptions and attitudes; axial coding for understanding how the categories identified in the open coding relate to each other, classifying categories under common themes; and, finally, selective coding in which a theory was sought that identifies a coherent phenomenon related to practitioners’ perceptions and attitudes toward inconsistency.

B. Results

The collected dataset was divided into two subsets: (1) data concerning perceptions of what inconsistency is, including definitions and examples provided by the participants, and (2) data concerning attitudes toward inconsistency, including emotions and strategies for handling inconsistencies. The summary of the results obtained for both of these subsets is presented below.

Inconsistency Perceptions:

The data analysis revealed a variety of ways in which inconsistency is manifested in RE, according to the definitions and examples of the participants. Importantly, participants typically did not provide abstract definitions of inconsistency, but rather used concrete examples as an explanation. During data analysis, two dimensions of classification emerged. One dimension is a distinction between two types of inconsistency: (i) between different descriptions at the same level of abstraction, and (ii) between different descriptions of the same product evolving over time. We refer to (i) and (ii) as horizontal and evolutionary inconsistency respectively1. The following quotes from answers to our question “What is inconsistency?” demonstrate the distinction between horizontal and evolutionary inconsistency.

Horizontal:

a) For example, when two conflicting requirements occur in different pages of the same document.

b) When different outputs are defined for the same input.

c) Using in a requirements document two different names for the same entity.

d) When part of the code is written using procedural approach and another part using object-oriented approach.

Evolutionary:

e) There can be inconsistency between what we implemented and the requirements.

f) I suppose that in the transition from requirements to implementation inconsistency occurs, because the requirements change over time but are not updated in the [requirements] documents, which creates inconsistency between the documents and the final product.

g) It had been required that the system would be developed according to certain coding standards, but later these standards were abandoned.

h) It had been required that the system would be implemented in C#, but due to unavailability of C# programmers, it was eventually implemented in Java.

Another dimension is a distinction we call 'internal vs. external manifestation,' referring to internal vs. external aspects of the software product. External aspects include all aspects visible to the end user; for example, functionality, performance and user interface. Internal aspects refer to aspects not visible to the end user; for example, the programming language, coding standards and internal development documents. For instance, examples (a), (b), (e) and (f) above were classified as external aspects, whereas examples (c), (d), (g) and (h) above were classified as internal ones. Combining the two identified dimensions, we obtain a 2x2 matrix, presented in Table 1, with a classification of the above exemplary statements.

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<th>TABLE I. THE CLASSIFICATION MATRIX</th>
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Inconsistency Attitudes:

As expected, most of the attitudes as reflected by the participants’ statements were negative toward inconsistency. This was expressed in their statements via frequent use of terms such as frustration, discomfort, anger, shame, and objection. Here are some of the answers received to the question "How do you feel about the inconsistency case you described?"

i) Bummer! I feel ashamed if I wrote that [inconsistent requirement specifications]; if someone else wrote that, I feel sorry for them.

j) Frustration. I like it when things are in order.

k) I associate consistency with truth. For me, being inconsistent is like lying. This is why it bothers me so much.
However, less negative answers were also received, for example:

- I don’t get upset over these things, but I worked with people who were extremely annoyed by it.
- If the inconsistency is in standards, it’s merely annoying but it’s not that serious.
- I don’t get worked up over them [inconsistencies].
- If it [inconsistency] has a reasonable explanation, I can live with it.

When asked to propose strategies for managing inconsistencies, all but 2 of the participants insisted on eliminating the inconsistency, often using terms expressing a sense of urgency. Examples:

- I stop it as soon as I see it. I don’t want the user to see it. It is very bad!
- This [the inconsistency] needs to be handled ASAP.
- They [inconsistencies] must always be resolved.

Another interesting phenomenon was the participants’ reactions towards a problem presented to them, to which an inconsistency-tolerant solution is clearly the obvious one. While they all agreed about the rationale, many of them switched to third person, or passive voice, when talking about this solution, despite the fact that they had been talking in first person and active voice during the entire interview. This switch was observed sometimes even within a single sentence while answering this question. Examples (bold font added by the authors to emphasize the switch):

- If I have a way to establish that it [the inconsistency] indeed occurs very rarely, and indeed it would cost me a lot to repair, then it may happen that they [there would release a system with bugs.
- This is a decision to be made by higher management. But I think this is very personal; I would probably repair [the inconsistency]. But it could be a strategic decision to release it like this.
- People can live with it [inconsistency]. I personally would repair it anyway.
- I do not usually produce inconsistencies. People must issue warnings about them.

As it turns out, although logically convinced, most of the participants had a difficulty as to accept a solution tolerating inconsistency. It seems that in the presence of such strong negative attitudes, rationale is not enough to establish real acceptance. Building on the statement of Finkelstein [10], not only do we need to change the way we think, we need to change the way we feel about inconsistency.

Analyzing the full set of the statements reflecting attitudes, through the lens of the classification matrix (Table 1), we found that these statements were more negative in the context of externally visible inconsistencies than in the context of internal ones, and similarly, more negative in the context of evolutionary inconsistencies than in the context of evolutionary inconsistencies. For example, statements (i) and (j) were given in the context of external/horizontal inconsistencies; (l) was given in the context of external/evolutionary inconsistencies; (m) was given in the context of internal/horizontal inconsistency; and finally, (o) was given in the context of internal/evolutionary inconsistency.

![Diagram](https://via.placeholder.com/150)

Fig. 1. Intensity of negative attitudes towards inconsistency

It is important to note that external/horizontal inconsistencies were brought up much more frequently than the other cases. This could be yet another indication of the intensity of resistance to inconsistency in this dimension combination.

### III. RESEARCH ROADMAP

The negative attitudes exhibited by our study participants are not surprising. However, the results of our preliminary empirical findings unveil the complexity, diversity and context sensitivity of the cognitive factors involved in inconsistency-related decision-making, and therefore the need for their further exploration. Such exploration may be instrumental in the following two aspects:

1. Based on the existing perceptions and attitudes of RE practitioners, proposals may be made on how to overcome cognitive barriers hindering the adoption of inconsistency management paradigms in industry.
2. Based on observing practitioners’ patterns of reasoning and decision making, methods for providing efficient support for inconsistency management may be identified;

In our preliminary study we mainly considered the first aspect, exploring practitioners’ perceptions of, and attitudes toward inconsistency. As this is an exploratory research in progress, the qualitative data elicited in the study may not reflect the full range of existing attitudes, and consequently not expose the full range of their dimension. Future research, eliciting additional data, and combining quantitative methods, may reveal further dimensions that can be useful for deeper understanding of the identified attitudes, the sources from which they stem, and directions for overcoming the barriers they pose.

A multi-dimensional analysis of practitioners’ perceptions and attitudes may also form a basis for an exploration of decision-making patterns of practitioners in the context of inconsistency management. As noted by Nuseibeh et al. [9], “The decision to tolerate an inconsistency is a risk-based decision: if the cost of fixing it outweighs the risk of ignoring it, then it
makes no sense to fix it.” (p. 27). Our future research plans include collecting empirical data from practitioners on their risk analysis and decision-making processes in different scenarios in which inconsistency may be encountered. Investigating patterns in the collected data may open the door to more efficient organizational and social processes, documentation practices, and decision support tools for inconsistency detection, resolution, measurement and management.

IV. CONCLUSIONS
Negative attitudes of practitioners towards inconsistency may pose significant barriers to a wider adoption of inconsistency management paradigms in industry. A thorough analysis of these attitudes, and the underlying perceptions, is a key factor in overcoming these barriers. In this ongoing research we empirically explored the existing perceptions and attitudes toward inconsistency. Our study revealed different intensity of negative attitudes in different contexts. We believe that our results demonstrate the usefulness of applying empirical human-centric research approaches, which have thus far not received attention in the context of inconsistency management in RE. Our future research plans include exploring further dimensions of inconsistency manifestations, and different contexts in which they may occur, as well as decision-making patterns demonstrated by practitioners when choosing inconsistency management strategies.

REFERENCES