Mitigation of Cognitive Biases in Innovative Software Engineering Projects: A Proposal

Alberto Guerral[1]

[1]CESAR, Recife Center for Advanced Studies and Systems
Apolo Street, Recife – Brazil

ahcg@cesar.school

Abstract.

Cognitive biases are critical in software engineering (SE) affecting replanning, failures and even cancellations. This work aims to identify and mitigate cognitive biases in the management of innovative projects in SE, in a large multinational company. Using the Design Science Research (DSR) method, a (1) Systematic Literature Review (SLR) will be carried out, (2) complementary research, (3) study of technological alternatives and (4) application of an artifact in the company's project portfolio to identify the behavior of the five most impactful biases in SE, proposing a framework with practical recommendations to eliminate them, contributing to future research in the industry.
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1. Introduction

The pervasive influence of cognitive biases on projects, particularly in the context of replanning and failure or cancellation, has emerged as a significant concern in the field of software engineering. Evidence points to a relationship between cognitive biases and their substantial impacts on software engineering projects [Mohanani et al. 2020]. However, despite this recognition, there is a notable dearth of comprehensive studies and research that explicitly focus on the direct implications of cognitive biases on projects, as well as effective solutions to alleviate the challenges they pose.

Although preliminary studies have identified the presence of cognitive biases in system development and software engineering, there remains a significant gap in exploring strategies to deal with these biases [Borowa et al. 2021], [Chattopadhyay et al. 2020], and [Mohanani et al. 2020]. Some of these biases include anchoring, fixation, confirmation, overconfidence, and optimism, each with distinct characteristics that profoundly influence the dynamics of software projects. Despite being recognized as critical factors, these biases remain relatively unexplored in the academic domain. Furthermore, strategic models designed to eliminate or mitigate these biases are conspicuously scarce in the existing literature.

The recognition of cognitive biases as powerful contributors to challenges in software engineering projects highlights the need for further investigation into their manifestation, impact, and potential countermeasures. This research work aims, in addition to contributing to the existing gap in the literature, investigating aspects of cognitive biases in the context of innovation software projects, as well as pragmatically helping companies that invest in these projects to substantially reduce the negative impact

of these biases. Building on existing studies, especially those by [Borowa et al. 2021], [Chattopadhyay et al. 2020], and [Mohanani et al. 2020], this research work seeks to provide a more comprehensive understanding of the key specific biases that significantly affect the outcomes of innovative software engineering projects, by identifying them, understanding how they impact these projects, and exploring mitigation mechanisms for them. In doing so, it aspires to contribute to the advancement of knowledge and the development of practical solutions to increase the success and resilience of software projects in the face of cognitive biases.

2. Research Problem

Cognitive biases are natural characteristic of the human mind, first observed by Kahneman and Tversky et al apud [Borowa et al. 2021]. They have their roots in the dual nature of human reasoning, with two distinct mental systems: System 1, responsible for quick judgments based on limited data, and System 2, which involves rational and logical thinking based on a larger set of data. If we do not deliberately analyze our choices, System 1 will make hasty judgments.

Cognitive biases arise from various sources and depend on each individual's thought process, including software engineers. Some biases result from development style, such as hyperbolic discounting, while others are caused by limited cognitive capacity [Chattopadhyay et al. 2020]. For example, the availability bias can lead programmers to choose solutions based on examples readily available in memory.

The concept of cognitive biases was first introduced in 1974 by Tversky and Kahneman apud [Chattopadhyay et al. 2020]. Since 1990, software engineering researchers have been examining these biases, reported in publications, especially those by [Mohanani et al. 2020]. Of the more than 200 cognitive biases found in management, psychology, and sociology studies, 37 different types have been examined in software engineering. These studies have shown that biases can distort code features, increase defect rates, and result in insufficient effort during requirements analysis.

Fleischmann et al apud [Zhou 2020] grouped cognitive biases into eight categories: perception, pattern recognition, memory, decision-making, action orientation, stability, social, and interest. The Cognitive Biases Codex, described by John Manoogian, 2016, categorizes more than 200 biases into four categories: too much information, not enough meaning, need to act fast, and what to remember.

Systematic deviations from the best choices and judgments are called cognitive biases and can compromise the success of a project [Wyrich et al. 2022]. [Mohanani et al. 2020] demonstrate that cognitive biases can occur in software engineering in several ways. The anchoring effect is the most frequently examined in the software engineering literature. Common problems in software engineering tasks can be explained by cognitive biases, helping to develop better practices and methods [Mohanani et al. 2022]. Studying biases is challenging because they can have different names depending on the field or context [Mohanani et al. 2020].

The most frequent biases in software engineering, according to [Mohanani et al. 2020], include:

A. Anchoring Bias: People rely too heavily on the first information received when

making decisions, disproportionately influencing subsequent thinking.

B. Fixation Bias: Inability to adequately adjust the evaluation of a situation, even with new information.

C. Confirmation Bias: Tendency to seek, interpret, and remember information that confirms existing beliefs [Rafiq et al. 2021].

D. Overconfidence Bias: Overestimation of one's abilities and aptitudes, leading to an illusion of control and neglect of useful information.

E. Optimism Bias: Tendency to produce overly optimistic estimates and predictions, influenced by the initial phase of projects and the ability to assess risks [Mohanani et al. 2020].

3. Related Work

The review of related studies in this work focuses on the analysis of cognitive biases in the context of project management for innovation in software engineering and related areas, such as computer science and information systems. In order to delineate the current research frontier, studies published from 2020 onwards were considered in this period, in which a significant gap in specific analyses in this area is observed.

The search for relevant literature, was conducted in renowned databases, including ACM Digital Library, IEEE Explore, and ScienceDirect - Elsevier. Initially, 149 papers were identified, which were subsequently filtered based on rigorous criteria, explained in Systematic Literature Review, resulting in a selection of 12 studies directly pertinent to the theme of cognitive biases in software and innovation projects.

Among these studies, various perspectives were explored. The study by [Kavitha et al. 2022], for example, investigated the role of cognitive biases in the responsible development of AI systems, while [Mohanani et al. 2021] examined the effects of these biases on the definition and framing of desiderata in software engineering projects. Some studies, such as [Catto and Maccari 2021], addressed broader themes related to innovation and project management without a specific focus on cognitive biases, while others, such as [Zhou 2020], explored less studied aspects, such as biases in technical communication. The study [Mohanani et al. 2020] was very comprehensive in terms of exploring cognitive biases in software engineering and can be applied to the study of innovation project management, since it is one of the most complete among those found. 37 cognitive biases were studied, grouped into 8 categories, and mitigation techniques were addressed for only 6 of them. Additionally, it was mentioned that proving a bias in a laboratory is not the same as proving that it has a significant impact on real projects.

In the study [Chattopadhyay et al. 2020], a field study involving ten developers was conducted to examine the prevalence of cognitive biases in the workplace and analyze their effects on development. The findings showed, through the studies of the Systematic Literature Review, that cognitive biases are common and negatively impact developers' problem-solving skills, such as exploration, sense-making, and contextualization. The fixation bias occurred most frequently in this category; it was linked to 477 developmental actions, of which 428 were reversed, although the study did not use mitigation techniques but only questioned developers if they had used actions to combat them.

Table 1 shows the degree of relationship between the studies and the research questions, obtained from reading and verifying whether each of them answered these questions. The variations were Weak (0), when it did not directly answer any question, Moderate (1-2), when it answered between one or two and Strong (3), when it answered the three research questions: RQ1: What are the main cognitive biases related to software innovation project management? RQ2: What are the impacts of cognitive biases on software innovation project management? RQ3: What strategies can be adopted to mitigate the effects of cognitive biases on software innovation project management?

Tabela 1. Degree of relationship between the studies and the research questions

STUDY	RQ1	RQ2	RQ3	DEGREE
[Kavitha et al. 2022]	X			MODERATE
[Borowa et al. 2021]		X		MODERATE
[Nicodeme 2021]				WEAK
[Mohanani et al. 2021]	X	X		MODERATE
[Mohanani et al. 2022]	X	X	X	STRONG
[Catto and Maccari 2021]				WEAK
[Geyer et al. 2022]				WEAK
[Buffardi 2023]		X		MODERATE
[Zhou 2020]				WEAK
[Wyrich et al. 2022]				WEAK
[Chattopadhyay et al. 2020]	X	X	X	STRONG
[Mohanani et al. 2020]	X	X	X	STRONG

Although the selected studies provided valuable insights into cognitive biases in the context of software engineering and innovation project management, few of them addressed specific strategies to mitigate them, and in a superficial way, leaving room for future study and research. This related work section highlighted the importance of additional research that effectively identifies and evaluates such strategies, aiming to promote more efficient and innovative project management in this domain.

4. Research Objectives

The main objective of the research is to identify the behavior, in innovation project management, of the five most common cognitive biases in software engineering in general and to develop a strategy to mitigate them.

To achieve the general objective, the research is divided into specific objectives, which include investigating and mapping the five most common cognitive biases in software engineering projects, analyzing how these biases affect the decision-making process in the management of innovation projects and the quality of the results, building an artifact using AI to identify these biases in a portfolio of projects of a large multinational company, and proposing a framework to mitigate these biases, based on consolidated organizational models.

The expected contributions of this research include promoting greater awareness of cognitive biases in the management of innovation projects in software engineering and offering practical guidelines to mitigate them. The strategies developed are expected to

improve the quality and effectiveness of projects, resulting in more impartial and effective solutions, contributing to the advancement of software engineering.

5. Proposed Methodology

The proposed research work plan involves using the DSR (Design Science Research) method.

According to [Vaishanvi and Library. 2009] and [Wieringa 2014], design science is defined as an approach that seeks to create things that serve human purposes. It involves the development of validated artifacts that meet identified needs, as well as the generation of justified theories about these artifacts to contribute to the knowledge base shared by design scientists.

The interaction between design and research activities is highlighted, with an emphasis on solving practical problems through design and validation of proposed solutions.

The philosophical line used by DSR is pragmatism, whose philosophical approach emphasizes the importance of practice, experience, and practical consequences in evaluating theories and beliefs. Pragmatists believe that the value of an idea or concept lies in its usefulness and effectiveness in solving real-world problems.

The thesis development method will consist of four stages:

1. **Use of Systematic Literature Review (SLR)** [Guerra 2024], to identify studies and solutions that aim to solve problems of cognitive biases in the management of innovative software projects.
2. **Deepening of the problem**, through the investigation of the greatest impacts of cognitive biases, how they can affect the management of innovation projects and definition of the biases to be the object of the work research.
3. **Evaluation of technological alternatives** for the construction of an artifact, using Artificial Intelligence (AI) LLM (Large Language Model), trained to identify cognitive biases in the data collected from the research. A research questionnaire will be formulated, in an objective way, to guide the interviews, where the main focus will be on the project planning phase, analyzing the responses of stakeholders, testimonies, facts and context. At this stage, research participants will be clearly informed about how AI will be used to process data, about open and closed questions, about the confidentiality of the data obtained and free from any type of constraint. By following these guidelines, the research will be conducted in an ethical and legally sound manner for the participants.
4. **Evaluation of results**, based on the application of the artifact, in approximately 50 innovative software engineering projects in a large multinational company. Once the presence of cognitive biases is detected, a framework containing recommendations for each project will be used. This framework will be developed based on organizational strategic concepts or models, with well-founded guidelines to mitigate each bias found.

6. Proposed Timeline

The author is a PhD student who began in the second half of 2023.

The first stage of the research, SRL, was completed in 2024 and focused on identifying the state of the art regarding the presence of cognitive biases in innovative software projects and possible existing mitigation techniques.

Based on the SLR, a scientific article was prepared, which was submitted and accepted for publication as a "Short Paper", at ICEIS 2024 – 26th International Conference on Business Information Systems, with issue number 183, entitled "Impact of Cognitive Biases on Innovative Software Engineering Projects". The event was held in the city of Angers, France, between April 28 and 30, 2024.

The proposed schedule also considers: 2024, Preparation of the Thesis Plan; 2025, Qualification of the Thesis Plan; 2025-2026, Evolution of the Thesis; 2027, Thesis Defense.

7. Final Considerations

Through the SRL, it was possible to identify studies and solutions that propose solutions to problems related to cognitive biases in software innovation projects. When reviewing the studies, it was observed that biases directly impact project management, influencing everything from the definition of objectives to the testing phase. Notably, study [Mohanani et al. 2020], offered a holistic approach, identifying 37 biases in software. However, the analysis also highlighted existing gaps, indicating that, despite the extensive research on cognitive biases in the human sciences, specific exploration in software engineering, especially in innovation project management, continues to be a field to be widely investigated. The complexity of these interactions requires continued attention and deeper analyses to develop effective strategies to mitigate biases and promote success in software innovation projects.

The works found related to software engineering are still few and very recent, and they are not applied to innovation projects. The main focus of this research work is to evaluate the presence of main cognitive biases in the management of innovation projects, using an artifact built with the help of AI, to understand their impacts and to apply a framework with mitigation recommendations for each bias found. Therefore, it is expected to contribute, in a pragmatic way, to the evolution of management, efficiency and quality of delivery of innovation software projects.

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