Cognitive Biases in Software Engineering: Debiasing through Reconception

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***Abstract*—Background: Cognitive biases are systematic errors in reasoning that can lead to inaccurate decision-making across all areas of software production, regardless of the domain, programming language, or development method. Given the central role of software across all sectors, such biases can result in large-scale inefficiencies, delays, and increased costs.**

Goal: While prior software engineering (SE) research predominantly focuses on specific tasks and quantitative methods, the vision of this paper is to study qualitatively how cognitive biases emerge, persist, and can be mitigated to improve decision-making throughout the Software Development Life Cycle (SDLC).

Method: This vision uniquely applies the concept of *reconception* as a theoretical lens to explore how software professionals' cognitive models influence their management of dialectical oppositions, such as project velocity vs product quality and open-source vs proprietary control. Utilising Socio-Technical Grounded Theory (STGT) and dialectical inquiry, it examines how reconceiving these oppositions affects cognitive models and decision-making processes.

Expected Outcome: A broad and high-level theoretical framework that explains how selected cognitive biases influence SE decision-making across the SDLC. The framework is developed through a two-phase STGT process: identifying salient bias categories in the first phase and focusing on the role of specific biases in shaping decision patterns in the second. This high-level theory will open new research opportunities for future investigations into bias-informed decision-making in SE.

Conclusion: This theoretical framework will support the development of empirically grounded debiasing strategies for more reliable decision-making in software engineering.

***Index Terms*—cognitive bias, decision-making, reconception, Socio-Technical Grounded Theory, dialectical inquiry, qualitative research**

I. Introduction

Cognitive biases are systematic errors in reasoning that lead to recurring mistakes in judgment. These biases originate from the necessity of simplifying complex judgment tasks into simpler operations [1]. An example of such bias is confirmation bias, which refers to the tendency to give more weight to information that aligns with our existing beliefs [2]. Cognitive biases can help explain various issues in software engineering (SE), such as difficulties in requirements elicitation, architecture, coding, testing, and maintenance, technology acceptance, and project management [2]–[6]. In turn, the impact of these biases can result in problems ranging from user dissatisfaction to reputational harm, loss of customers, reduced productivity, increased costs, and longer lead times for organisations offering software-based services [7].

Today, software is present in every sector of the economy. It is the cornerstone of innovation, driving efficiency and enabling new business models across industries. This economic value of software has long been understood. For example, the European Commission has acknowledged the importance of software for Europe's industrial competitiveness and growth [8]. Recently, this acknowledgement has extended to open-source software [9]. In the United States, software is considered the cornerstone of 5G technology, which has the potential to drive significant economic growth [10]. However, realising the economic potential of software largely depends on its effective development and quality. Even small advances in software development efficiency and quality, especially by addressing cognitive biases, can result in significant reductions in effort and costs, as well as improved outcomes for end users.

Cognitive biases are closely tied to how individuals perceive and conceptualise information in decision-making—perception involves the active recognition of differences, while conception refers to interpreting and assigning meaning to these differences [11]–[13]. *Reconception*, combining the two, extends this by examining how individuals actively reshape their cognitive models when facing contradictions [14]. It is a continuous, proactive process through which individuals frame dialectical oppositions, such as tensions, by reshaping their decision-making based on past experiences and anticipated futures [14]. In SE, such opposition can be project velocity vs software quality [15], benefits vs limitations of development practices [16], or open source vs corporate control, often impacted by biases like status quo, overconfidence, and optimism bias.

Problem statement: As cognitive biases impact everyone [17], they can disrupt all facets of software development, regardless of the industry, programming language, or project management approach. This can result in decreased team productivity and negatively affect product quality, ultimately leading to significant additional costs that could have been avoided. Therefore, cognitive biases in SE pose significant long-term challenges [2]. This vision paper has identified the following gaps in empirical SE research on cognitive biases:

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- Cognitive bias studies in SE often focus on specific tasks within the Software Development Life Cycle (SDLC), lacking insights into how biases arise in broader, cross-cutting decisions [1].
- Cognitive bias studies in SE are often carried out in labs, lacking real-world field studies [2].
- Cognitive bias studies in SE primarily focus on quantitative methods, with a noticeable lack of qualitative research [1], [7].
- SE research should examine the social and cognitive processes in software development that give rise to cognitive biases [7].

Addressing these gaps requires moving beyond purely technical perspectives and laboratory-bound quantitative approaches. It is also essential to consider the contextual, interpretive, and dynamic aspects of decision-making in SE practices. These factors influence various SDLC stages and affect the technical, organisational, and collaborative elements of software projects.

Accordingly, we aim **to study how cognitive biases emerge, persist, and can be mitigated in SE decision-making throughout the SDLC.**

To reach this goal, this vision paper will draw on cognitive psychology and apply Socio-Technical Grounded Theory (STGT) [18], [19] complemented by dialectical inquiry [20]. Our research vision is to take a cross-disciplinary approach to develop a broad, empirically grounded, and high-level theoretical framework that supports more reliable decision-making in SE. By focusing on how individuals and teams perceive, interpret, and respond to—that is, reconceive—complex and often contradictory dialectical demands during decision-making within the SDLC, this study aims to address long-term challenges and opportunities in SE research and practice that currently remain outside the mainstream.

II. Background and Related Work

Human behaviour and cognition are critical areas of research in SE. Many studies focus on human decision-making within this field by applying theories and concepts from psychology. These studies address various issues, including architectural decision-making [21], software project management, and software engineering and development paradigms [2], [22]. In addition, they explore psychological and sociological aspects, such as motivation [23]. Together, these studies demonstrate the impact of human cognition and behaviour in succeeding in SE.

Cognitive psychology, a subdiscipline of psychology, explores the mental processes behind behaviour and action [24]. In human decision-making—a central topic of cognitive psychology—individuals process perceived and stored information into choices that lead to action [25]. Perception and conception are fundamental cognitive processes through which individuals make sense of their environment [26]. Perception involves active recognition of differences in the surrounding environment, while conception refers to how individuals structure and give meaning to those differences within their broader cognitive framework [11]–[13].

Human decision-making is both a calculated and systemic process that relies on a continuously updated cognitive model of the world to simultaneously and iteratively develop and evaluate alternatives, using predictions, heuristics, judgments, utility comparisons, and bodily sensations, i.e., somatic markers [27]. Thus, decision-making relies on cognitive as well as emotional processes [28]. The outcomes are compared to expectations—consciously or subconsciously—eliciting responses like satisfaction or regret, which reinforce learning, rationalisation, and sensemaking over time [27].

However, when operating under uncertainty or information overload, human decision-making often relies on shortcuts [29]. While classical decision theory assumes complete rationality, empirical research shows that individuals frequently deviate from optimal decision-making due to bounded rationality—a concept that acknowledges our limited knowledge and computational capacity when faced with complex situations [29], [30]. As a result, alternative strategies that deviate from optimal are often used, leading to erroneous decisions, i.e., cognitive biases as a side product [17], [31].

Cognitive biases are not solely negative. They often play a functional role in enabling decision-making efficiently, reducing the overwhelming amount of information to a manageable size [29]. Faced with the opposing pressures of making accurate decisions while relying on limited information, individuals often rely on cognitive shortcuts that echo past experiences. While generalising from our past experiences may be useful, due to the uncertain nature of the world, some features of earlier experiences may be irrelevant or misleading when applied to new decisions [25]. Enhanced understanding of these shortcuts and the biases they create can improve judgment and decision-making under uncertainty [17].

Reconception can extend these understandings. It is an active process of perception and conception through which individuals reshape their cognitive models when faced with opposition, such as tensions or contradictions [14]. It emphasises that cognition is not static or purely reactive, but rather, individuals constantly reinterpret their surroundings based on their situated context, prior experiences, and expectations about the future [12], [32]. In this view, information is not seen as an objective, external resource, but as something constructed through continuous meaning-making of differences in a dynamic environment [13].

Reconception, as a dialectical process, involves continuous interaction between past experiences and anticipated futures [14]. Individuals perceive shifts or oppositions in their environment related to, for example, conflicting demands, changes in goals, or emerging uncertainties, and attempt to resolve or reframe them through reflective meaning-making. This may lead to revised beliefs, updated priorities, or adjusted responses. Notably, reconception does not necessarily result in absolute resolution; contradictions may persist, or they may be temporarily suppressed or suspended. Even in such cases, individuals' cognitive frameworks develop.

In the SE context, reconception is particularly relevant because decision-making involves highly dynamic socio-technical environments where experts must constantly balance competing goals, interpret incomplete or ambiguous information, and respond to evolving requirements. For example, they may encounter tensions between project velocity and product quality [15], perceived benefits and limitations of development practices [16], or open-source versus corporate control. Moreover, the encountered contradictions are often exacerbated by such biases as status quo bias—the tendency to prefer current practices and resist change, even when change could be beneficial—overconfidence bias—the tendency to overestimate one's abilities or control over situations, resulting in overlooking risks and complexities in decision-making—and optimism bias—the tendency to make overly positive predictions about future outcomes (cf. [2], [7]). Reconception thereby offers a valuable lens for understanding how cognitive biases are reinforced or mitigated within situated decision processes.

A central mechanism in this process is oppositional framing that helps to explain how individuals cognitively organise oppositions they encounter [20]. They may frame oppositions in different ways, such as polarising (either-or), where merely one view is seen as viable, complementary (both-and), where opposing views can co-exist, or mutually implicating (more-than), where opposing views reinforce each other. This dialectical framing becomes central when navigating complex decision-making contexts, as it influences how oppositions are understood, responded to, and ultimately resolved. Recognising these framing patterns can provide deeper insights into how cognitive biases emerge and persist in SE contexts, particularly under conditions of uncertainty and evolving project demands.

Despite the recognition of these challenges, no definitive catalogue of cognitive biases exists. Over 200 biases have been identified across psychology, sociology, and management research [7]. Studies within the information systems (IS) domain provide a prevalent overview of these biases (e.g. [33], [34]). Fleischmann et al. [33] synthesised eight categories of cognitive biases: perception, pattern recognition, memory, decision, action-orientated, stability, interest, and social biases, based on their impact on the decision-making process. In turn, a systematic mapping study in SE highlights the need for targeted research to better understand the social and cognitive processes behind bias formation [7]. The study also identifies gaps in the development of debiasing techniques and theoretical foundations, emphasising the need to adapt existing debiasing methods for SE contexts, develop new strategies, and empirically evaluate their effectiveness.

III. Research Objectives

The main goal of this research vision is to empirically explore cognitive biases and debiasing techniques in SE practices by examining how cognitive biases emerge, persist, and can be mitigated in SE decision-making throughout the SDLC. To achieve this, the following sub-objectives are set.

- **Examine the role of reconception in cognitive bias formation.** We will examine how software professionals' cognitive models are shaped by reconception when facing tensions and contradictions during decision-making processes, focusing on how biases develop and persist.
- **Identify social and cognitive processes underlying biases.** We will investigate the social and cognitive factors contributing to the formation and persistence of cognitive biases in SE, emphasising the interaction between individual cognition and team and organisational dynamics.
- **Evaluate the impact of reconception on bias mitigation.** We will assess if reconception processes, specifically the reframing of oppositions, can reduce the impact of cognitive biases in decision-making within SE projects.
- **Develop and adapt context-specific debiasing strategies.** We will propose and refine debiasing strategies grounded in the empirical findings on reconception, ensuring their relevance to SE contexts.

This novel understanding can be utilised for more effective, cross-cutting decision-making across the SDLC.

IV. Methodology and Research Process

Cognitive psychology and SE often use experimental, quantitative methods to study human cognition and biases [7], [24]. While effective for discrete aspects, these deductive approaches may fall short on analysing complex thought processes [24], [29]. To address this, qualitative methods are increasingly seen as essential for examining situated, goal-directed cognition influenced by organisational goals, social structures, and interpersonal interactions [24].

This study aims to shift the focus from identifying what biases exist to how they emerge and persist within specific socio-technical settings. To achieve this, we adopt qualitative methods that are well-suited for capturing the complexities of human behaviour in SE [35]. These methods enable the development of rich descriptions, the exploration of relationships, and theory building [36]. Given that qualitative research methods have been identified as critical yet underutilised in SE for investigating cognitive biases [7], we apply them here to investigate the situated nature of such biases.

A. Socio-Technical Grounded Theory (STGT)

Grounded Theory (GT) offers a systematic way to inductively build theory from data [37], and its socio-technical extension (STGT) is tailored for SE contexts [18], [19]. As SE is a fairly young discipline, with limited mature, domain-specific theories, inductive approaches like GT are needed for developing context-specific foundations [38]. Our interpretivist stance, where knowledge is viewed as socially constructed rather than objectively discovered [39], further justifies STGT: It allows us to investigate how experts themselves make sense of their context and how it shapes socio-technical outcomes.

To achieve our research objectives, STGT will be used to develop an empirically grounded theoretical understanding of the phenomenon. Rather than starting with fixed hypotheses, we follow an inductive process focused on how cognitive biases emerge, persist, and can be mitigated in SE decision-making. Through iterative data collection and analysis, we

build and refine preliminary explanations, aiming to construct empirically grounded theory. This approach is particularly well-suited for exploring tensions and contradictions inherent in cognitive processes, laying the foundation for a dialectical examination of biases.

B. Dialectical Inquiry

Dialectical opposition—such as tensions, paradoxes, and contradictions—significantly influences decision-making. Understanding dialectical reasoning is crucial because individuals may be tempted to believe that if one view is correct, another seemingly contrasting view must then be incorrect [29]. Dialectics aims to overcome such dichotomous thinking, making it a method well suited to investigate sociotechnical change processes [20], such as decision-making in SE projects.

Cognitive psychology explores thought processes that often involve dialectical structures, where concepts evolve over time through patterns of transformation [29]. In this dialectical process, an existing thesis, representing the status quo, is challenged by an antithesis, signifying a new idea or alternative viewpoint, followed by negotiations optimally leading to a resolution known as synthesis, which in time becomes a new thesis [29], [40]. However, the process may lead to trade-offs, unresolved tensions, or the preservation of the status quo due to power struggles [40]. Moreover, dominant actors may suppress opposition groups to protect their own interests in the established order [40], [41].

Dialectical inquiry [20] is a research strategy that draws on these ideas to analyse how opposing perspectives, prevalent in decision-making, interact and evolve. In SE, dialectical inquiries have examined such oppositions as the benefits versus limitations of development practices [16], dialectical tensions within global software teams [42] and conflicting viewpoints in software process theories [15]. These examples illustrate the presence of dialectical inquiries in SE, although not always explicitly framed as such.

Within the broader framework of STGT, dialectical inquiry will be used to understand how experts reconceive tensions and contradictions by reshaping their cognitive models and how this process contributes to the emergence, persistence, and mitigation of cognitive biases in SE decision-making. This methodology allows us to investigate how software professionals frame oppositions as either polarising (*either-or*), complementary (*both-and*), or mutually implicating (*more-than*). These framings are shaped through reconception, a process where individuals actively reshape their cognitive models in response to contradictions, uncertainties, and evolving demands. Dialectical inquiry can thereby reveal how biases emerge and persist within decision-making processes influenced by competing priorities and dynamic project environments.

C. Data Collection Methods

Qualitative data will be collected through interviews, observations, and written documents. Qualitative interviews have successfully uncovered cognitive strategies and biases across domains such as finance [43], lean implementation [44], and design engineering [45], as well as SE [4], [46]. In alignment with this research stream, qualitative semi-structured interviews will be employed.

Observations will be conducted in two ways: through *direct observations* in real-world decision-making settings, such as meetings, and *participant observations*, using scenario-based methods [47] The first type of observation provides data about the real-world aspects of the research problem [48], while the second method, combined with verbal responses allows us to capture insights into the thoughts and considerations of the participants [29]. These verbal thinking-aloud methods are well established in cognitive psychology [30].

Finally, written documents will range from business cases and project justification documents to project plans, meeting memos, and project reviews. Collectively, these multiple sources of evidence—interviews, observations, and documents—will provide comprehensive insights into the phenomenon, allowing triangulation across qualitative data.

As data is collected over time with iterative analysis, it allows tracing decision-making progress, evaluating consequences of the decision, and adapting data collection accordingly. To remain open to emerging insights, we will acknowledge our own assumptions, including potential biases, and treat these assumptions as hunches to be explored and refined through abductive reasoning [19]. Constant comparison and memoing across data types support analytical flexibility, theory development, and researcher bias mitigation [18].

D. Preliminary research process

Our preliminary research process, detailed below, follows the full STGT approach, comprising both basic and advanced stages (see Figure 1). In the basic stage, we utilise the categories synthesised by Fleischmann et al. [33]. This will help us identify the most salient categories and determine which biases within those categories should be the focus of our later research. In the advanced stage, informed by the findings from the basic stage, we will concentrate on selected biases across the SDLC. During this stage, we will also examine how upstream and downstream decisions interact and how biases are either reinforced or mitigated throughout the SDLC phases. Although the process is described below in terms of consecutive stages, it is highly iterative.

1) Basic Stage: Data Collection and Analysis:

- **Phase 1 - Lean Literature Review:** A preliminary state-of-the-art literature review, i.e., a lean literature review [19], on cognitive biases and reconception will be conducted. This will provide foundations for theory development and the empirical phase of the study.
- **Phase 2 - Design:** This phase will begin with refining the research design and aligning the theoretical framework with the methodological approach of STGT informed by dialectical inquiry. This phase will ensure methodological clarity and rigour and provide foundations for empirical data collection.
- **Phase 3 - Pilot Data Collection and Analysis:** In this phase, we aim to explore, on the category level (cf.

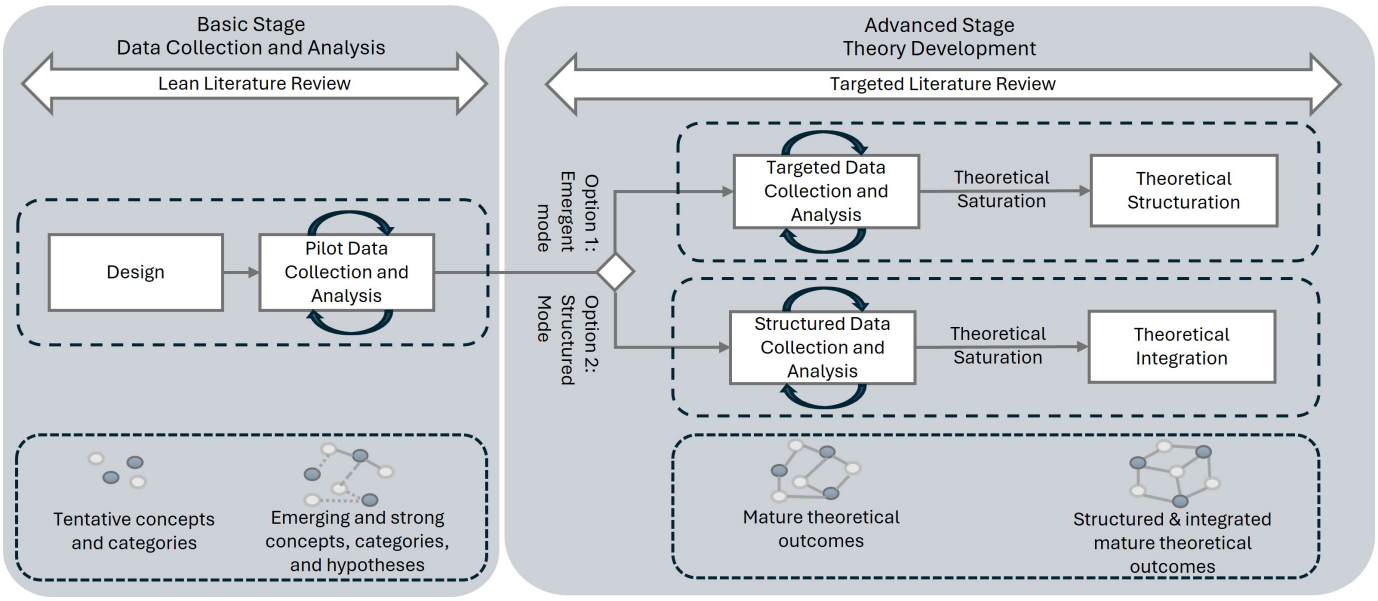

Fig. 1. STGT process (adapted from [18])

[33]), how cognitive biases emerge and are framed in SE decision-making. Pilot data collection will be conducted through semi-structured interviews with our industry partners. The participants are selected from diverse roles, including executive and strategic decision-makers, middle management, technical experts, and developers, to capture a broad range of perspectives on decision processes. The focus will be on dialectical opposition in decision-making, how these are cognitively and socially framed (reconception), and on identifying emergent categories of cognitive biases. Data will be analysed inductively using STGT principles and dialectical inquiry. This phase will serve to identify salient bias categories and refine interview protocols and analytical focus, laying the foundation for a deeper investigation in the advanced stage into specific biases within the full SDLC.

2) Advanced Stage: Theory Development:

- **Phase 1 - Targeted Literature Review:** The advanced stage of the study will begin with an in-depth literature review, i.e., targetted literature review [19], focusing on the findings of the basic stage. This targeted review allows the comparison of the original findings with existing studies, helping to position them within the broader research context and addressing gaps in the literature.
- **Phase 2 - Structured/Targeted Data Collection and Analysis** Building on the initial insights, this phase will involve targeted data collection through qualitative interviews, observations, and document analysis. In-depth interviews will further examine the role of reconception and cognitive framing in bias formation, persistence, and mitigation, focusing on the specific biases. Direct and participant observations will trace how cognitive biases manifest and evolve across different stages of the SDLC, with each stage potentially vulnerable to different biases. The document analysis will examine project documentation for identifying patterns of dialectical reasoning, bias persistence, and bias mitigation efforts, or the lack thereof. This targeted data collection aims to deepen our understanding of the social and cognitive processes behind biases and to empirically evaluate how reconception contributes to their mitigation.
- **Phase 3 - Theory Development:** Theoretical saturation—reached when additional data no longer yield new insights—will signal the completion of data collection and analysis. The theory development relies on the application of the full STGT method. Its goal is to identify key patterns of cognitive biases—how they emerge, persist, and can be mitigated—in software engineering decision-making throughout the SDLC, as well as the relationships among these patterns. The synthesised findings will be validated in collaboration with key industry stakeholders to ensure practical relevance. The ultimate goal is to develop and adapt context-specific debiasing strategies grounded in the realities of SE practice.

V. Research Vision: Broad and High-Level Theoretical Framework

The vision is to develop a broad and high-level theoretical framework that depicts how cognitive biases emerge, persist, and can be mitigated in SE decision-making. Rather than focusing on specific tasks of software development, the aim is to offer insights into cognitive biases as cross-cutting features of SE practice, across the SDLC. The theoretical framework will include the interplay between individual cognition, social interaction, and organisational pressures, highlighting that biases are not just internal deviations but socially and contextually shaped phenomena.

The theoretical outcome—an overarching conceptual framework—maps the key components of cognitive biases in the SE decision-making process, including the cognitive and social mechanisms involved in bias formation, the situational triggers and dialectical opposition that give rise to bias, the dialectical framing and reconception processes of decision-making, and strategies for bias mitigation. The framework is developed through a two-stage STGT process: the first stage identifies salient bias categories using Fleischmann et al.'s [33] categorisation to determine which specific biases warrant further focus. The second stage examines selected biases across the SDLC, investigating how they emerge and evolve at different phases, how upstream and downstream decisions interact, and how biases are reinforced or mitigated over time. The framework is not intended to offer depth on any single construct but rather to lay out a structured view that can guide further research by identifying critical areas for focused theoretical development.

Aligning with the principle of STGT, this broad and high-level theory will serve as a research agenda, offering premises for future investigations into the identified components:

- **Focused and high-level theoretical outcomes**, such as taxonomies of cognitive bias types in SE, classifications of reconception strategies, or mappings of framing patterns in different decision contexts.
- **Broad and in-depth theoretical outcomes**, which may integrate these characteristics into comprehensive models of cognition and decision-making in complex, socio-technical SE environments.
- **Focused and in-depth theoretical outcomes**, including detailed accounts of how specific biases manifest in SE practice, when and why certain debiasing strategies succeed or fail, and how reconception processes vary across roles, teams, or organisational cultures.

By offering structured yet broad theoretical premises, this research vision aims to provide not only a foundation for further theory-building in SE but also a basis for practical improvement of human decision-making in complex, real-world settings where cognitive, social, and organisational dynamics are inherently intertwined. The empirically grounded theoretical foundations offer solid strategies to support more reliable decision-making across the SDLC.

VI. Risks and Threats to Validity

Every design choice in this vision paper has strengths, weaknesses, and associated risks, which we summarise below.

Risks: This study may face risks such as limited access to the industry, participant reluctance, and difficulty articulating cognitive processes. To address these, we will leverage existing networks, ensure confidentiality, and use clear, concrete language to support recall and reflection.

Construct validity: Defining key concepts such as cognitive bias and reconception poses a risk of ambiguity, particularly given the interpretative nature of our study. To mitigate this, we will provide clear conceptual definitions, involve participants from varied roles (executive, managerial, and technical) to diversify perspectives, and conduct systematic, iterative analysis to ground our findings in the realities of participants. These steps support the conceptual coherence and interpretive integrity of the study.

Internal validity: Rather than seeking a causal explanation, this study focuses on understanding how cognitive biases are experienced and managed in practice. To enhance internal validity, we will triangulate across interviews, observations, and documents to develop a rich and multidimensional understanding of decision-making processes. The use of STGT ensures that insights are grounded in data through iterative analysis, constant comparison, and theory development.

External validity: Rather than aiming for statistical generalisation, we adopt analytical generalisation by linking empirical findings to broader theoretical constructs. In addition, we will provide rich contextual descriptions of the empirical settings, enabling others to assess the applicability of our results to similar contexts.

Reliability: In qualitative research, the reliability of findings depends on the transparency and reflexivity of the research process. As interpretations are inherently subjective and can be influenced by researchers' biases, we will continuously reflect on our own backgrounds, assumptions, and research interests. We will document the data collection procedures and analytical steps, and create a data repository to ensure traceability and transparency. These measures help ensure a clear chain of evidence and minimise the impact of researcher bias on the findings.

VII. Conclusion

Software is essential across all industries, making its cost and quality significant concerns. However, cognitive biases impact everyone [17] and can disrupt all aspects of software development. This disruption can lead to decreased productivity, compromised quality, and unnecessary long-term costs.

This vision paper has proposed a broad and high-level theoretical framework (cf. [19]) to understand how cognitive biases emerge, persist, and can be mitigated across the SDLC. By identifying the key components and interactions underlying biases in SE, the proposed theory lays the groundwork for a structured research agenda. This agenda will support the development of taxonomies, in-depth empirical studies, and eventually more comprehensive theories—advancing both scientific understanding and practical strategies for more reliable decision-making in SE.

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