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### Towards debiasing code review support

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# Towards debiasing code review support

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**Abstract—Background:** Current state-of-the-art established that cognitive biases appear during code review. They significantly impact the creation of feedback and how developers interpret it. These biases can lead to illogical reasoning and decision-making, violating one of the main hypotheses supporting code review: developers’ accurate and objective code evaluation. **Objective:** This paper explores harmful cases caused by cognitive biases during code review and potential solutions to avoid such cases or mitigate their effects. **Method:** We design several prototypes covering confirmation bias and decision fatigue. We rely on a developer-centered design approach by conducting usability tests and validating the prototype with a user experience questionnaire (UEQ) and participants’ feedback. **Results:** Our interim findings show that some techniques could be implemented in existing code review tools as reviewers will accept them and help prevent behavior detrimental to code review. **Conclusion:** This work provides a first approach to treating cognitive bias in code review. The developed prototypes will evolve into fully functional tools, with an extensive evaluation with developers.

**Index Terms**—cognitive bias, code review, user-centered design

## I. INTRODUCTION

One of the many software development activities taken to ensure code quality is *code review*. Code review consists of methodical code assessments that follow pre-defined guidelines and are supported by various tools to identify potential bugs, increase code readability, help developers learn the source code (i.e., code knowledge transfer), etc. Practically, code review is performed by a developer (i.e., a *reviewer*), usually other than the *author* of the code being reviewed. This reviewer relies on tools to read the code and make comments, ask questions, and request changes that the author will take care of. Once the author and the reviewer are satisfied, the code is included (i.e., *merged*) into the code base. The main goals of code review are to prevent defects, enable knowledge transfer, check the code readability, enforce maintainability standards, etc., on recently modified source code [2], [33].

Like many software engineering activities, code review not only involves applying technical knowledge but heavily relies on social interactions between the reviewer and the author of the code [7], [11], [28], [34]. Such social-based activities

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are heavily influenced by cognitive and social aspects that are often neglected. This research focuses on *cognitive biases* [1], specifically their triggers and potential effects on code review quality already identified by the current state-of-the-art [3], [28]. First, we list factors triggering cognitive biases for the reviewer or the author. Second, we design solutions to avoid such biases or mitigate their effects.

In this short paper, we report on our emerging and interim findings from the design of the solutions addressing the triggers of *confirmation bias* and the effects of *decision fatigue*. For that, we follow a user-centered (here, developer-centered) design approach [27], [29], [30]. In the first phase, we explore potentially harmful situations and design theoretical solutions to prevent or mitigate biases. In the second phase, we aim to improve the designed solutions by conducting usability tests with beginners using a prototype based on an existing code review tool. These tests serve as feedback to gather the users’ requirements for an acceptable solution. To achieve this, we iterate multiple times over the prototype. Finally, we conduct an evaluation of the prototype’s final result by testing the user experience with the standard *User Experience Questionnaire* (UEQ) [36], [37] to test whether developers accept our solution. With the prototype as a final result and an evaluation of its usability (see our replication package [18], [19]), we propose a first work on solving relationships between cognitive bias and code review. The prototype will serve as the basis for developing a functional tool to evaluate the impact of our solutions on confirmation bias and decision fatigue.

## II. BACKGROUND

In psychology, cognitive biases (denoted biases hereafter) refer to instances where human cognition consistently generates representations that are systematically distorted when compared to objective reality [17]. Unlike logical fallacies, which are arguments based on invalid reasoning, biases are patterns of thinking that affect how we interpret new information and processes. They are applied systematically and influence our behavior, opinions, and decisions. Causes of biases are rooted in heuristics [1], [17], [21], [22], [42]: shortcuts or rules of thumb used by our brain to solve a problem or judge a situation quickly. For instance, people with a higher social position tend to apply stereotypical views on others more often than those with a more precarious position, who invest more time and energy in social judgment [17]. However, precisely identifying the exact causes of a specific

bias is challenging [28] as the generative mechanism for many cognitive biases is still an open question [28].

To eliminate biases (i.e., *debiasing*), previous research has shown that neither applying more effort nor being more experienced in a field helps mitigate cognitive biases [13]. However, training on cognitive biases and applying specific techniques can make a substantial difference. This has been demonstrated not only for experts in a field but also to affect the judgment of non-experts [8].

a) *Cognitive biases in software engineering*: Given their intensive human effort and involvement, cognitive biases have also been explored for various software engineering activities [7], [11], [14], [28], [34]. For instance, Barroso et al. [3] investigated developers’ personalities’ influence on their tasks. They have shown that the quality of the product depends on the interaction between members of the team combined with their professional capabilities and, therefore, on the interpretation and reactions to feedback. Going further, Spadini et al. [40] investigated the effect of existing review comments on code review and showed that reviewers are subject to availability bias when performing reviews. More recent research has evidenced the importance of appropriate techniques to deal with cognitive biases during code review, such as checklists to potentially lower developers’ cognitive load [15]; avoiding destructive criticisms not to decrease motivation [16]; or guideline to deal with confusion during code reviews [10]. In a recent study, Fagerholm et al. [11] have identified future research directions for cognition in software engineering, including perception and software quality, which have received very little attention.

b) *Confirmation bias*: One of the most researched cognitive biases in psychology is the confirmation bias. It refers to the collection, interpretation, analysis, and research for information in a way that confirms one’s prior beliefs instead of searching for information disproving them [20], [32]. In practice, once the mind adopts an opinion, it does everything to support it, leading to wrong decisions defying the sense of logical reasoning. For instance, the positive test bias leads developers to test only to confirm the code instead of disproving it [26], [34], [41]. In general, and not only during tests, one’s goal should be to fail the code to reduce defect density [6].

c) *Decision fatigue*: A high number of decisions to make, each requiring the processing of information over a short period of time, leads to the depletion of internal resources (*ego depletion* [4]). When ego depletion manifests as decision fatigue, it causes attention deficit and impulsive decisions and leads to postponing decisions to look at them later [9]. Finally, people subjected to decision fatigue tend to have an impaired ability to make trade-offs; they prefer acting in a passive role and making irrational judgments. Unfortunately, such changes in behavior are hard to recognize [31].

### III. DEBIASING CODE REVIEW

From the literature, we notice that cognitive biases and their effects can be explained as illustrated in Figure 1: we consider that **triggers** can initiate a cognitive bias which **impacts** the investigated activity. A trigger is a specific environmental

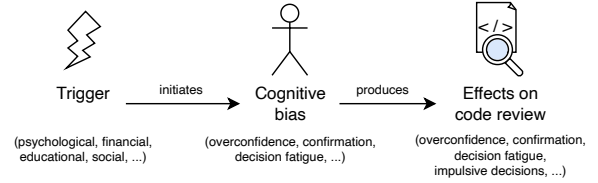


Fig. 1. Relationship between triggers, cognitive biases, and their effects.

TABLE I  
SCENARIOS FOR CONFIRMATION BIAS

<b>Trigger:</b>	The developer gets low-quality feedback, hurting their self-esteem.
<b>Effect:</b>	The developer refuses recommendations from the feedback to protect their self-esteem.
<b>Remedies:</b>	(a) <i>Constructive feedback</i> . Prevent the bias by advising the reviewer on how to give constructive feedback. (b) <i>Review feedback</i> . Prevent the bias by suggesting that the reviewer ask another developer for feedback about their review.
<b>Trigger:</b>	The reviewer is under time pressure due to circumstances.
<b>Effect:</b>	The reviewer tries to validate the existing code instead of analyzing it objectively.
<b>Remedy:</b>	(c) <i>Encourage brainstorming</i> . Mitigate the impact by providing a form with empty solution fields to encourage the reviewer to think about multiple solutions.

condition that enables a cognitive bias. Multiple elements can potentially trigger one cognitive bias, and one cognitive bias, in turn, can produce multiple effects. This initial work focuses on debiasing code review, which is essential in software quality assurance, to avoid confirmation bias (i.e., *triggers*) and mitigating potential *effects* of decision fatigue, which are well documented in the literature. As mentioned in Section II, precisely identifying the causes and effects of a specific bias is challenging as the underlying mechanisms are poorly understood. In our first step, we are interested in finding practical solutions to debias code review support. Based on our review of the literature, we define a first set of scenarios in which triggers and effects can be identified and reproduced.

a) *Confirmation bias*: Research in psychology investigated confirmation bias a lot [6], [23], [34], providing a solid basis to research its relations to software engineering, especially to modern code review. We focus on two scenarios described in Table I, with potential solutions. We assume that how a reviewer builds the feedback influences the developer’s perception and, therefore, their acceptance of the feedback (first line in Table I). Also, when reviewers see code changes, they are exposed to code that influences their perception during review [40]. We assume that under time pressure, this phenomenon becomes more pronounced: a reviewer tends to search for fast review approval instead of correct implementation (second line in Table I).

b) *Decision fatigue*: Many triggers can initiate decision fatigue [4], [39]. We focus on the scenarios described in Table II. The first and second scenarios consider that a reviewer needs motivation to tackle new code or potentially new topics. Humans tend to perform small tasks where they are rewarded early: this behavior is called hyperbolic discounting [24]. However, during code review, a reviewer may get assigned a significant number of reviews to do or review code requiring specific knowledge. Our assumption is that when decision fatigue is triggered due to unfavorable circumstances for starting

TABLE II  
SCENARIOS FOR DECISION FATIGUE

<b>Trigger:</b>	The reviewer is over-solicited.
<b>Effect:</b>	The reviewer misses motivation to do reviews and postpones them for later (i.e., procrastination).
<b>Remedies:</b>	(d) <i>Scheduled reviews</i> . Prevent the bias by limiting the number of reviews to a maximum number and a calendar to schedule. (e) <i>Observe needed time</i> . Prevent the bias by reminding the reviewer to halt when too much time is needed for review.
<b>Trigger:</b>	The reviewer misses knowledge about a specific topic in the code.
<b>Effect:</b>	The reviewer misses motivation to do reviews and postpones them for later (i.e., procrastination).
<b>Remedy:</b>	(f) <i>Find an expert</i> . Prevent bias by assigning the best fitting reviewer according to their experience in the topic.
<b>Trigger:</b>	The reviewer works at times of day known for decreased internal resources (e.g., the end of the working day or after lunch).
<b>Effect:</b>	The reviewer makes impulsive comments instead of constructive suggestions for the author.
<b>Remedy:</b>	(g) <i>Guide with comments</i> . Mitigate the impact by guiding the reviewer through the files with comments made by the author.
<b>Trigger:</b>	The reviewer lacks experience in doing code reviews.
<b>Effect:</b>	The reviewer skips code changes or parts of the code, leading to a lower understanding of the code.
<b>Remedy:</b>	(h) <i>Help commenting</i> . Mitigate the impact by providing a form with keywords to help the reviewer include all essential elements.

tasks intensive in cognitive resources, the reviewer tends to procrastinate. In the third scenario, decision fatigue leads the reviewer to make impulsive comments. Our assumption is that the comments will be expressed in a familiar way, leading to destructive feedback instead of constructive feedback. In the last scenario, our assumption is that understanding the code is vital to making constructive comments for the author. A review that is influenced by decision fatigue (i.e., not taking all the elements into account) might provoke misleading feedback for the author. Mitigating the impact of biases on code review requires dealing with either the trigger initiating the bias or its effects. The former or the latter might be better suited, depending on the scenario.

#### IV. DESIGN OF THE CODE REVIEW SUPPORT

We design and test potential solutions to address the remedies described in Tables I and II following a user-centered (here, reviewer/developer-centered) design process [27], [29], [30] to iteratively guide the building of our support. Figure 2 provides an overview of the process: due to time constraints, we limited the development to two iterations (i.e., *usability tests*), concluded by a *user experience test*, performed with a different group of users than the one involved in the first and second usability tests. The tested solutions are developed as HTML prototypes. We relied on two groups of users (selected using convenience sampling): three for the first and second usability tests (all students in the final year of the MSc program in computer science at the University of Namur) and five for the final user experience test (one junior developer and four senior developers with experience in code review). We employ eight participants in total, which, according to Faulkner [12], helps identify, on average, more than 80% of the problems. More details about the participants are available in our replication package [19].

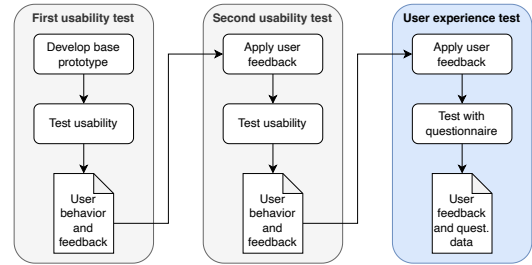


Fig. 2. Design, prototyping, and evaluation

##### A. First usability test

First, we create an initial prototype based on the web tool Gerrit (<https://www.gerritcodereview.com>), similar to what can be found on GitHub. Then, we implement the remedies listed in Tables I and II, identified by the current state-of-the-art, using the following techniques. Our user-centered design approach allows us to test and refine those techniques iteratively. All the prototypes and results can be found in our replication package [19]. The usability tests analyzed the usages of the instrumented prototype, followed by a debrief session. For each technique, we defined one or more scenarios where the student acted as a developer or a reviewer, depending on the technique, and was given a task to perform. After each scenario, the first author debriefed with the student. Due to space constraints, we only report a summary of our observations in Table III.

a) *Technique 1.1 – Advice*: The goal is to help the reviewer create constructive feedback [16]. The first technique is based on advice displayed as a list. This list can be opened by clicking the button *I need advice*. A popup shows a list containing the advice. The advice originates from literature investigating how to achieve constructive feedback [5], [43].

b) *Technique 1.2 - Form*: Because under decision fatigue, reviewers tend to make incomplete comments [15], the idea of a pre-structured form seems an appropriate choice. This way, the reviewer does not have to think about structuring the comment. It should include the identification of a problem, a justification of why the discovery is considered a problem, and a suggestion to solve it. Here, three empty fields are available to encourage the reviewer to brainstorm multiple suggestions, promoting more thorough and considered feedback.

c) *Technique 1.3 – Guide*: To avoid the user skipping changes or even entire files from being reviewed, a guide is offered just before starting the review [10]. This guide consists of a certain amount of comments written by the author. They contain an explanation of why a certain change was made. When launching the guide, the reviewer’s attention is immediately drawn to the first comment, surrounded by a red border, as decided by the author. When the reviewer decides they understand the change, they click the button *Next* to go to the next comment. Once having been through every step, the reviewer starts the actual review.

##### B. Second usability test

We improved the prototype based on the observed behavior and the participants’ suggestions. Some techniques were

TABLE III  
SUMMARY OF THE USABILITY TESTS OBSERVATIONS

Usability test 1	
<b>Technique 1.1</b>	⊕ Most users apply the advice after reading it.
<b>Advice</b>	⊕ The short formulated advice is appreciated.
<i>Remedies (a), (b), (f)</i>	⊖ The popup button is not always noticed. ⊖ Not everybody wants to be advised. ⊖ Background color confuses participants.
<b>Technique 1.2</b>	⊕ All fields get filled out.
<b>Form</b>	⊕ The form provides a coherent structure.
<i>Remedies (c), (d), (e) (h)</i>	⊖ Only one solution is given. ⊖ Some feel overwhelmed.
<b>Technique 1.3</b>	⊕ Everyone uses the guide.
<b>Guide</b>	⊕ No code change is skipped.
<i>Remedies (d), (e), (g)</i>	⊖ The guide could bias the reviewer's comment. ⊖ The Next button is not intuitive.
Usability test 2	
<b>Technique 2.1</b>	⊕ The advice is noticed and read immediately.
<b>Advice</b>	⊕ The advice impacts the overall comment.
<i>Remedies (a), (b), (f)</i>	⊖ Green color signifies already complete. ⊖ Participants mistake inciting items for to-do items.
<b>Technique 2.2</b>	⊕ All participants use the technique.
<b>Example</b>	⊕ Saves time to think about structure.
<i>Remedies (c), (h)</i>	⊕ Comment analysis could be automated. ⊖ Participants type the keywords manually.
<b>Technique 2.3</b>	⊕ All participants use the technique.
<b>Quick search</b>	⊖ Some only use the quick search without commenting.
<i>Remedies (c), (f)</i>	
<b>Technique 2.4</b>	⊖ Most participants do not use the technique.
<b>Expert feedback</b>	⊖ Most users are concerned about annoying colleagues.
<i>Remedies (b), (f)</i>	
<b>Technique 2.5</b>	⊕ Launch button is noticed faster.
<b>Guide</b>	⊕ Understanding the Next button is intuitive.
<i>Remedies (d), (e), (g)</i>	⊕ The Next button acts as an obligation to comment. ⊖ Unable to make comments inside the guide.

improved, two new ones were added, and one was removed.

a) *Technique 2.1 - Advice:* In the current iteration, the advice popup was transformed into a drop-down list immediately visible when the comment tool is opened. Unlike in previous iterations, this change ensures that every participant notices and reads the advice. As stated in Table III, the green background does not show positive effects. Also, though most elements can be used like in a checklist, some can not because they are intended to incite the reviewer to analyze the code from another perspective.

b) *Technique 2.2 - Example:* A new technique emerged from the advice technique 1.1 in the previous iteration. Here, the technique uses an example, and participants follow the structure presented in the example. The feedback confirms appreciation, as shown in Table III.

c) *Technique 2.3 - Quick search:* As requested in the first iteration, tasks should take less effort (i.e., fewer intermediary clicks). The form used before is now replaced with a quick search. It was used in different ways: first commenting, then searching for code snippets related to the comment, or searching for a solution before commenting. In the latter case, however, the comment only refers to the selected solution from the search without further explanation.

d) *Technique 2.4 - Expert feedback:* As for the previous technique, another help was requested: providing expert feedback allows for countering the effects of decision fatigue

(a) Combination of advice and example.

(b) Combination of quick search and expert feedback.

Fig. 3. Combinations of techniques.

when the reviewer is prone to take a passive role. However, as observed during the tests, most participants do not use the expert feature because they feel they are experienced enough or do not want to annoy a senior colleague.

e) *Technique 2.5 - Guide:* In this iteration, the launch button for the guide is bigger and thus better visible, and the button used to get to the next step is placed in a more understandable location. As stated in Table III, it has a positive impact. However, all participants complained about being unable to comment while using the guide.

### C. Final prototype

Multiple participants suggested combining techniques (and their corresponding remedies) during the second usability test.

a) *Technique 3.1 - Advice:* Techniques 2.1 and 2.2 have been combined to create constructive feedback, as shown in Figure 3a. A new button is added to prepare the comment structure faster: it copies the key phrases “Identified problem”, “Why is it a problem” and “Suggestions” into the comment field. The advice is located beneath the example.

b) *Technique 3.2 - Assistant:* Techniques 2.3 and 2.4 are combined to mitigate decision fatigue’s effects (Figure 3b).

c) *Technique 3.3 - Guide:* Addressing the negative point of Technique 2.5 (⊖ in Table III) would not support the intended effect. Being able to comment continuously hinders the reviewer from following the guide to understand the code as a whole. Therefore, Technique 3.3 remains equivalent to Technique 2.5.

## V. USER EXPERIENCE TEST

This preliminary evaluation focuses on feedback about the user interface and its usability, not the psychological aspects. Those are left for future work with a full-extent experience with a larger number of junior and senior developers.

An evaluation proceeds with each of the five participants, all experienced developers (one junior and four seniors), familiar with code review, as follows: (i) we ask the participant about their experience in code review; (ii) depending on the answer, we explain and demonstrate what code reviews are and how tools can be used to assist the code review process; (iii) for

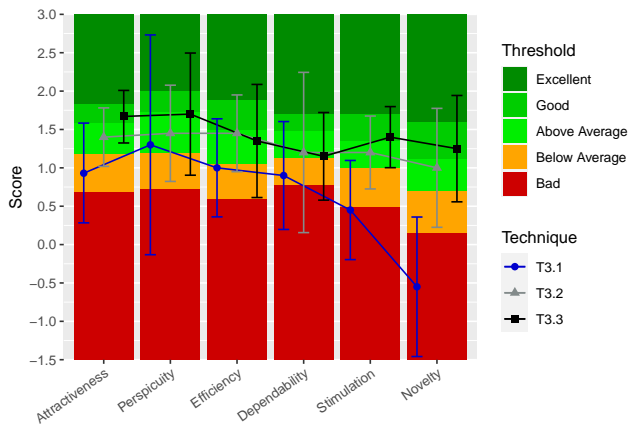


Fig. 4. Results of the UEQ benchmark for the advice with example (T3.1), the quick search with expert feedback (T3.2), and the guide (T3.3). Dots denote mean values, and error bars indicate 95% confidence intervals.

each technique (Technique 3.1-3.3), we explain to the participant about the task (one per technique) to perform and proceed with the test. The explanation, however, takes place without mentioning the investigated aspects concerning cognitive biases. This is necessary so as not to bias the participant’s opinion; (iv) after completing each task, the participant is asked to fill out a standard User Experience Questionnaire (UEQ) [25], [35], [36], [38]; (v) the experimenter (first author) also notes observations about the participants’ behavior. The UEQ is a heavily validated state-of-the-art questionnaire measuring user experience following the predefined scales: Attractiveness (do users like or dislike the product), Perspicuity (is it easy to get familiar with the product?), Efficiency (can users solve their tasks without unnecessary effort?), Dependability (does the user feel in control of the interaction?), Stimulation (is it exciting and motivating to use the product?), and Novelty (is the product innovative and creative?). Additionally, we ask every participant after the questionnaire for personal feedback about the tested technique. All the collected data (UEQ and observations) are available in our replication package [19].

We analyze questionnaire responses for each technique to evaluate if it improves user experience using the UEQ Data Analysis Tool [35]. This tool provides a quantitative analysis, converting responses from 1 to 7 to a scale of -3 (most negative) to +3 (most positive). It classifies the scale values into five categories, from excellent to bad, based on a benchmark of user interfaces [37]. Results for the three techniques are reported in Figure 4. Given the preliminary nature of the evaluation, the small sample size results in a less accurate quantitative analysis (as confirmed by the sometimes large confidence intervals in Figure 4), yet it still indicates trends in user experience, supported by the additional qualitative feedback and observations (not reported in this short paper due to space constraints).

The UEQ results indicate that users perceive *Technique 3.1 - Advice* as understandable and easy to learn. Users rated the technique poorly on the stimulation scale, indicating it was neither exciting nor motivating, and perceived it as conventional. Users also find *Technique 3.2 - Assistant* interesting,

exciting, motivating, efficient and easy to use, aligning with the technique’s goals. The technique is seen as innovative in code reviews. Overall, the user experience results are positive, reflecting the feedback, but responses focus more on the *quick search* feature than the *expert feedback*. Finally, users find *Technique 3.3 - Guide* highly attractive and interesting, with clear indications of it being stimulating and innovative. It also receives positive evaluations for efficiency, with users feeling it meets expectations by providing support.

## VI. CONCLUSION AND FUTURE WORK

Our base assumption was that non-constructive feedback during code review provokes *confirmation bias*. Our preliminary results from applying *Technique 3.1 - Advice* suggest that reviewers prefer guided, pre-defined structured comments but are generally unmotivated to follow written advice. Overall, advice and examples are used quickly, without spending more than a few seconds to integrate them in the comments. Reviewers are willing to incorporate examples into the review process, and most agree that this technique has positive effects. While this research does not quantitatively measure the extent to which the technique prevents confirmation bias, it includes a prototype solution and tests user experience. Further investigation with different experimental setups are necessary for representative results on confirmation bias prevention.

Our base hypothesis suggested that *decision fatigue* during code review leads to incomplete comments. From this, we proposed *Technique 3.2 - Assistant*. User experience tests show that the search tool encourages adding code snippets to comments and is well-received once users understand its purpose. This technique shows significant potential to mitigate decision fatigue. Conversely, the expert feedback tool is seen as annoying by senior colleagues, with reviewers avoiding it because they are confident in their comments. Currently, the expert feedback prototype cannot mitigate decision fatigue but could be improved through design adjustments. Overall, the design and layout significantly influence the effectiveness of the tools. User understanding and willingness to use a technique depend heavily on the interface design, suggesting that alternative designs might yield better results.

Our hypothesis also supports that *decision fatigue* during code review leads to skipping short, large, or complex changes. *Technique 3.3 - Guide* can prevent this by helping reviewers address important changes individually. User experience tests show that reviewers consistently use the guide, following it to the end without skipping any changes. Participants appreciated the guide, indicating it effectively prevents decision fatigue from causing skipped reviews. Thus, the technique helps mitigate certain effects of decision fatigue during code review.

The limited participant number constrained our quantitative data, and some responses’ high variance calls for further investigation. However, these results still helped identify tendencies and refine prototypes. For instance, user feedback suggests that automating repetitive review tasks and providing context-sensitive feedback (using, for instance, generative AI) could help reduce decision fatigue. Our future research will focus

on design aspects for better outcomes and further prototype development for a full-scale evaluation of the impact on triggers of confirmation bias and the effect of decision fatigue.

## REFERENCES

- [1] H. R. Arkes, "Costs and benefits of judgment errors: Implications for debiasing," *Psychological Bulletin*, vol. 110, no. 3, pp. 486–498, 1991, place: US Publisher: American Psychological Association.
- [2] D. Badampudi, M. Unterkalmsteiner, and R. Britto, "Modern Code Reviews—Survey of Literature and Practice," *ACM Transactions on Software Engineering and Methodology*, vol. 32, no. 4, 2023.
- [3] A. S. Barroso, J. S. Madureira, M. S. Soares, and R. P. do Nascimento, "Influence of human personality in software engineering—a systematic literature review," in *International Conference on Enterprise Information Systems*, vol. 2. SCITEPRESS, 2017, pp. 53–62.
- [4] R. F. Baumeister, E. Bratslavsky, M. Muraven, and D. M. Tice, "Ego depletion: Is the active self a limited resource?" *Journal of Personality and Social Psychology*, vol. 74, no. 5, pp. 1252–1265, 1998, place: US Publisher: American Psychological Association.
- [5] R. Bee and F. Bee, *Constructive Feedback*. CIPD Publishing, 1998.
- [6] G. Calikli and A. Bener, "Empirical analyses of the factors affecting confirmation bias and the effects of confirmation bias on software developer/tester performance," in *Proceedings of the 6th International Conference on Predictive Models in Software Engineering*, ser. PROMISE '10. New York, NY, USA: ACM, Sep. 2010, pp. 1–11.
- [7] S. Chattopadhyay, N. Nelson, A. Au, N. Morales, C. Sanchez, R. Pandita, and A. Sarma, "A tale from the trenches: cognitive biases and software development," in *Proceedings of the ACM/IEEE 42nd International Conference on Software Engineering*. Seoul South Korea: ACM, Jun. 2020, pp. 654–665.
- [8] J. A. O. G. da Cunha and H. P. de Moura, "Towards a substantive theory of project decisions in software development project-based organizations: A cross-case analysis of it organizations from brazil and portugal," in *2015 10th Iberian Conference on Information Systems and Technologies (CISTI)*. IEEE, 2015, pp. 1–6.
- [9] S. Danziger, J. Levav, and L. Avnaim-Pesso, "Extraneous factors in judicial decisions," *Proceedings of the National Academy of Sciences*, vol. 108, no. 17, pp. 6889–6892, Apr. 2011.
- [10] F. Ebert, F. Castor, N. Novielli, and A. Serebrenik, "An exploratory study on confusion in code reviews," *Empirical Software Engineering*, vol. 26, no. 1, p. 12, Jan. 2021.
- [11] F. Fagerholm, M. Felderer, D. Fucci, M. Unterkalmsteiner, B. Marculescu, M. Martini, L. G. W. Tengberg, R. Feldt, B. Lehtelä, B. Nagyvárad, and J. Khattak, "Cognition in Software Engineering: A Taxonomy and Survey of a Half-Century of Research," *ACM Computing Surveys*, vol. 54, no. 11s, pp. 1–36, Jan. 2022.
- [12] L. Faulkner, "Beyond the five-user assumption: Benefits of increased sample sizes in usability testing," *Behavior Research Methods, Instruments, & Computers*, vol. 35, no. 3, pp. 379–383, Aug. 2003.
- [13] B. Fischhoff, *Debiasing*. Cambridge University Press, 1982, p. 422–444.
- [14] M. Fleischmann, M. Amirpur, A. Benlian, and T. Hess, "Cognitive biases in information systems research: A scientometric analysis," *Tel Aviv*, p. 23, 2014.
- [15] P. W. Gonçalves, E. Fregnan, T. Baum, K. Schneider, and A. Bacchelli, "Do explicit review strategies improve code review performance? Towards understanding the role of cognitive load," *Empirical Software Engineering*, vol. 27, no. 4, p. 99, Jul. 2022.
- [16] S. D. Gunawardena, P. Devine, I. Beaumont, L. P. Garden, E. Murphy-Hill, and K. Blincoe, "Destructive Criticism in Software Code Review Impacts Inclusion," *Proceedings of the ACM on Human-Computer Interaction*, vol. 6, no. CSCW2, pp. 1–29, Nov. 2022.
- [17] M. G. Haselton, D. Nettle, and D. R. Murray, "The Evolution of Cognitive Bias," in *The Handbook of Evolutionary Psychology*. John Wiley & Sons, Ltd, 2015, pp. 1–20.
- [18] T. Jetzen, "Towards cognitive biases aware tools for improved code review: a user-centered approach," Master's thesis, University of Namur, 2022.
- [19] T. Jetzen, X. Devroey, and B. Vanderose, "Psychopass: Towards debiasing code review support replication package," <https://doi.org/10.5281/zenodo.14803013>.
- [20] M. Jørgensen and E. Papatheocharous, "Believing is Seeing: Confirmation Bias Studies in Software Engineering," in *2015 41st Euromicro Conference on Software Engineering and Advanced Applications*, Aug. 2015, pp. 92–95.
- [21] D. Kahneman, *Thinking, fast and slow*. Macmillan, 2011.
- [22] D. Kahneman and A. Tversky, "Prospect theory: An analysis of decision under risk," *Econometrica*, vol. 47, no. 2, pp. 363–391, 1979.
- [23] J. Klayman, "Varieties of Confirmation Bias," in *Psychology of Learning and Motivation*, J. Busemeyer, R. Hastie, and D. L. Medin, Eds. Academic Press, Jan. 1995, vol. 32, pp. 385–418.
- [24] D. Laibson, "Golden Eggs and Hyperbolic Discounting\*," *The Quarterly Journal of Economics*, vol. 112, no. 2, pp. 443–478, May 1997.
- [25] B. Laugwitz, T. Held, and M. Schrepp, "Construction and Evaluation of a User Experience Questionnaire," in *HCI and Usability for Education and Work*, ser. LNCS, A. Holzinger, Ed., vol. 5298. Springer, 2008, pp. 63–76.
- [26] L. M. Leventhal, B. E. Teasley, and D. S. Rohlman, "Analyses of factors related to positive test bias in software testing," *International Journal of Human-Computer Studies*, vol. 41, no. 5, pp. 717–749, Nov. 1994.
- [27] J.-Y. Mao, K. Vredenburg, P. W. Smith, and T. Carey, "The state of user-centered design practice," *Communications of the ACM*, vol. 48, no. 3, pp. 105–109, 2005.
- [28] R. Mohanani, I. Salman, B. Turhan, P. Rodriguez, and P. Ralph, "Cognitive Biases in Software Engineering: A Systematic Mapping Study," *IEEE Transactions on Software Engineering*, vol. 46, no. 12, pp. 1318–1339, Dec. 2020.
- [29] D. Norman, *The design of everyday things: Revised and expanded edition*. Basic books, 2013.
- [30] D. A. Norman and S. W. Draper, *User Centered System Design; New Perspectives on Human-Computer Interaction*. USA: L. Erlbaum Associates Inc., 1986.
- [31] G. A. Pignatiello, R. J. Martin, and R. L. Hickman, "Decision fatigue: A conceptual analysis," *Journal of Health Psychology*, vol. 25, no. 1, pp. 123–135, Jan. 2020.
- [32] A. Rainer and S. Beecham, "A follow-up empirical evaluation of evidence based software engineering by undergraduate students," *NA*, Jun. 2008.
- [33] C. Sadowski, E. Söderberg, L. Church, M. Sipko, and A. Bacchelli, "Modern code review: a case study at google," in *Proceedings of the 40th International Conference on Software Engineering: Software Engineering in Practice*, ser. ICSE-SEIP '18. ACM, May 2018, pp. 181–190.
- [34] I. Salman, B. Turhan, and S. Vegas, "A controlled experiment on time pressure and confirmation bias in functional software testing," *Empirical Software Engineering*, vol. 24, no. 4, pp. 1727–1761, Aug. 2019.
- [35] D. M. Schrepp, "User experience questionnaire handbook - ueq-online.org," Dec. 2019.
- [36] M. Schrepp, A. Hinderks, and J. Thomaschewski, "Applying the User Experience Questionnaire (UEQ) in Different Evaluation Scenarios," in *Design, User Experience, and Usability. Theories, Methods, and Tools for Designing the User Experience*, ser. LNCS, D. Hutchison, T. Kanade, J. Kittler, J. M. Kleinberg, A. Kobsa, F. Mattern, J. C. Mitchell, M. Naor, O. Nierstrasz, C. Pandu Rangan, B. Steffen, D. Terzopoulos, D. Tygar, G. Weikum, and A. Marcus, Eds., vol. 8517. Springer, 2014, pp. 383–392.
- [37] —, "Construction of a Benchmark for the User Experience Questionnaire (UEQ)," *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 4, no. 4, p. 40, 2017.
- [38] —, "Design and Evaluation of a Short Version of the User Experience Questionnaire (UEQ-S)," *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 4, no. 6, p. 103, 2017.
- [39] H. H. Sievertsen, F. Gino, and M. Piovesan, "Cognitive fatigue influences students' performance on standardized tests," *Proceedings of the National Academy of Sciences*, vol. 113, no. 10, pp. 2621–2624, Mar. 2016.
- [40] D. Spadini, G. Çalıklı, and A. Bacchelli, "Primers or reminders?: the effects of existing review comments on code review," in *Proceedings of the ACM/IEEE 42nd International Conference on Software Engineering*. Seoul South Korea: ACM, Jun. 2020, pp. 1171–1182.
- [41] B. E. Teasley, L. M. Leventhal, C. R. Mynatt, and D. S. Rohlman, "Why software testing is sometimes ineffective: Two applied studies of positive test strategy," *Journal of Applied Psychology*, vol. 79, no. 1, pp. 142–155, 1994, place: US Publisher: American Psychological Association.
- [42] A. Tversky and D. Kahneman, "Judgment under Uncertainty: Heuristics and Biases," *Science*, vol. 185, no. 4157, pp. 1124–1131, Sep. 1974.

[43] A. Waggoner Denton, "Improving the Quality of Constructive Peer Feedback," *College Teaching*, vol. 66, no. 1, pp. 22–23, Jan. 2018.