

Creating Happier and More Productive Software Engineering Teams through AI and Machine Learning

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Abstract

Software engineering is a highly collaborative and socially interactive activity. During Covid-19 software teams were bound to work in a distributed manner and the rapid overnight shift in employment conditions has significantly negatively affected developers' productivity and well-being. Post-pandemic, most teams have not returned to their pre-pandemic way of working, preferring to use more virtual tools rather than physically seeing each other. Individuals' well-being while working remotely is influenced by their emotional stability. Low emotional stability among employees can worsen physical, social, and psychological stress. Many software companies have recognized the importance of individual well-being for the success of their organization. Despite its recognized importance and relation with employee productivity and performance, its accurate identification within hybrid team collaboration remains challenging. In this research, our objective is to employ Artificial Intelligence (AI) and Machine Learning (ML) tools for studying and analyzing the well-being of hybrid Agile software development teams. We will focus on examining their verbal communication (speech), non-verbal cues (emotions, head movement, and gaze patterns), and textual communication. The analysis will be guided by the PERMA+4 framework, which encompasses positive emotion, engagement, relationships, meaning, achievement, physical health, mindset, environment, and economic security. The goal is to integrate the research findings into the teams through a continuous feedback mechanism to enhance the teams' happiness and productivity.

Keywords

Agile software development, hybrid software development, well-being, emotions, AI, machine learning

1. Introduction

Software engineering is a very socially interactive activity where developers collaborate and work together to develop and maintain software products [1]. Communication and coordination among developers have a substantial impact on the success of software projects [2]. However, with the outbreak of the COVID-19 pandemic, companies asked their employees to work remotely from their homes regularly. Although the concept of work from home and remote work is not a new phenomenon in software development, work from home differs from regular remote work in COVID-19. Development teams who used to work primarily in co-located environments were forced to shift their working mode from co-location to regular remote work. The rapid overnight shift in employment conditions has significantly negatively affected developers' productivity and well-being [3]. Over time, the development teams get facilitated by engineering and knowledge-sharing, for instance, cloud computing, virtual private networks, and communication tools such as Zoom, Slack, Jira, and others. Companies are increasingly allowing their teams to work remotely. A survey by Bao

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et al., [4] shows that 56% of companies have allowed their teams to work remotely regularly while 52% of companies have allowed a hybrid format.

Modern software engineering is increasingly dependent on the well-being of large globally distributed communities and their social networks in software development [5][6]. Several studies have described the relationship between developers' well-being and their workplace performance and productivity, and that the individuals with higher well-being exhibit better performance [7]. Software development is a socio-technical phenomenon [8] and the software project's success or failure is a combination of both technical and non-technical aspects [9]. From existing literature, it is evident that technical aspects that generate technical debt (TD) have been heavily investigated during the last decade to understand its functioning from various perspectives [10]. Meanwhile, non-technical aspects that encompass process, social, and people debts have remained latent and relatively unexplored. Therefore, it is essential to study human-related aspects that are critical for the productivity and success of any project, ensuring the fulfillment of performance requirements for software development organizations.

In software engineering, there is an emerging interest in studying human-related aspects that influence the productivity and performance of software developers. Software development activities involve cognitive processing tasks [11]. The connection between affects (emotions, moods, feelings) and cognitive processing activities influence the individual's performance and productivity [12]. Recent research revealed that software developers experience an emotional rollercoaster throughout the development process [13]. Developer's productivity is closely linked to their emotional state and job satisfaction [14]. Specifically, the unhappiness of developers leads to low cognitive performance, lack of motivation, and mental distress [15].

Many software companies are striving to enhance the performance and productivity of their teams. To enhance the team's performance, companies need to focus on the individual well-being of their employees [16]. It is generally recognized that the well-being of employees significantly contributes to their productivity and, thus, enhances the overall performance of their teams [17]. The individual's well-being within a workplace goes beyond personal implications, as it directly impacts the prosperity of the organization [18]. A happy, healthy, and engaged workforce has been associated with enhanced productivity, lower staff turnover, improved team collaboration, and increased customer satisfaction—elements essential for the enduring success of an organization [16]. Hence, understanding and promoting individual well-being yields mutual benefits for the individual, the team, and the organization.

The increasing significance of digitalization, globalization, and collaborative work environments in today's dynamic world demands the implementation of advanced methodologies for evaluating and fostering individual well-being within team-based organizations [19]. However, despite well-being's crucial role in fostering productivity and ensuring organizational success, its correct identification within hybrid team collaboration remains challenging [18]. Additionally, existing assessment tools for individual well-being often rely on time-consuming surveys and questionnaires, limiting the capacity to offer real-time feedback. This research aims to automatically determine individual well-being in teamwork by employing ML-based data analysis approaches. Considering the significance of well-being in the workplace and the potential of ML to unveil novel insights, this research can make valuable contributions to both academic discussions and the practical applications of organizational management.

2. Research Questions

Considering the significance of well-being in the workplace and the potential of ML to unveil novel insights, the following research questions are designed to address the aims of this project:

Primary RQ: How to improve hybrid team performance through a constant feedback mechanism.

- **RQ1:** How well-being within the team is related to team performance?
- **RQ2:** How collaboration within a team is related to team performance and well-being in the team?

To address these research questions, four studies have been planned. Figure 1 below depicts which research question will be addressed in which study and how the studies are intended to produce knowledge that will be valuable for subsequent studies.

Table 2
Planned Studies

No	Research Question	Research Design	Data Collection
1	Question 1	Systematic Literature Review (SLR)	Literature Review
2		Case Study 1	Co-located Agile software development teams
3	Question 2	Case Study 2	Hybrid Agile software development teams
4		Multiple Case Study	Industry professionals

3. Research Method and Implementation

This research project aims to fill the research gap in social software engineering by automatically determining individual well-being in teamwork by employing ML-based data analysis approaches. The objective is to analyze the verbal communication (speech), non-verbal cues (emotions, head movement, and gaze patterns), and textual communication of hybrid Agile software development teams. The analysis will be guided by the PERMA+4 framework [20], which encompasses positive emotion, engagement, relationships, meaning, achievement, physical health, mindset, environment, and economic security. The goal is to integrate the research findings into the teams through a continuous feedback mechanism to enhance the teams' happiness and productivity.

We use empirical research methods to address the aim of this research. The tools developed by Gloor's team at MIT [21], will measure the communication and emotions (e.g., Happiness) of the teams by gathering verbal and non-verbal data from the tools teams are using. We will analyze the data and feed the results back to the teams through virtual mirroring, which we integrate into the daily scrum and retrospectives of the agile teams. We will leverage existing tools that are built to measure personality characteristics (FFI), moral values, and other personal preferences using natural language processing (NLP), and other honest signals extracted from facial expressions body movements, and speech. As an example of intervention to increase team performance, we plan to create virtual tribes that congregate at a virtual coffeemaker. Figure 1 below shows the overview of tools developed by Gloor's team to measure and increase collaboration among teams while Figure 2 shows the PERMA+4 a work-related well-being framework.

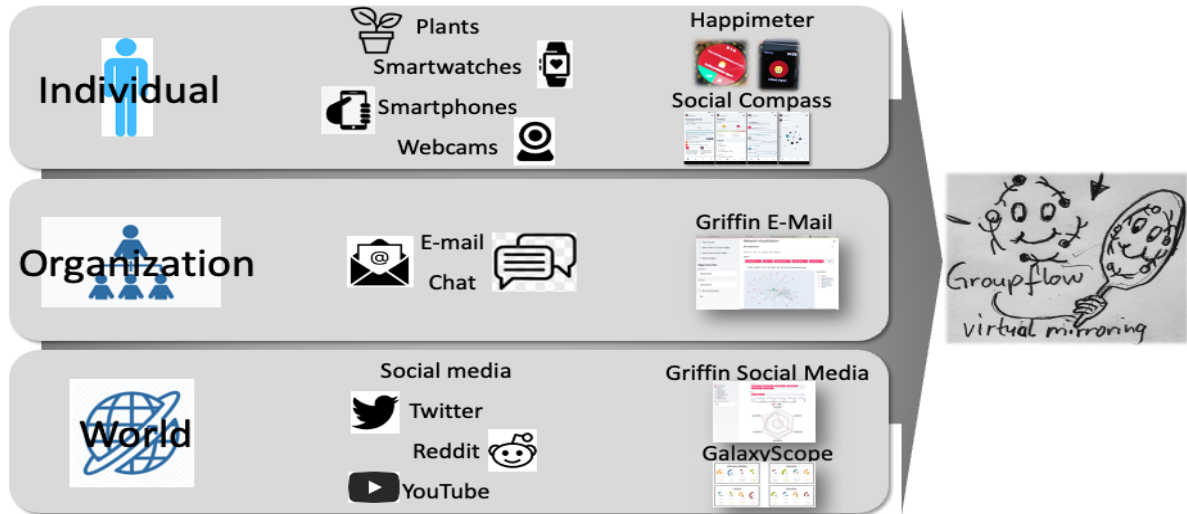


Figure 1: Overview of tools developed by Gloor’s team to measure and increase collaboration in teams.

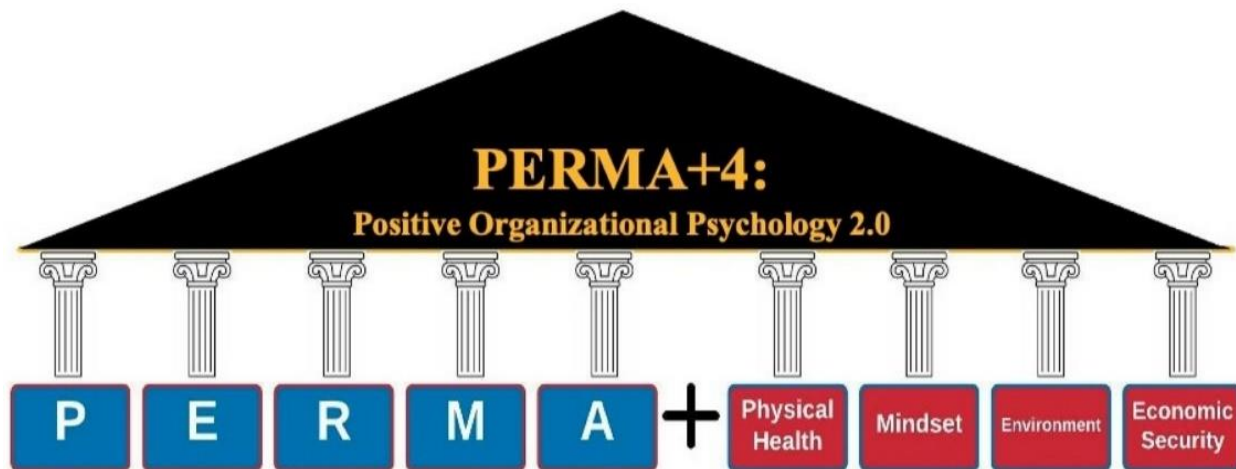


Figure 2: A Framework for work-related well-being

In the pilot phase, we will collect data from and collaborate with the hybrid software development teams from the LUT bachelor-level course “Capstone Project for Software and Systems Engineering”, which has yearly 100 students from two campuses working on real software projects offered by Finnish and global companies. In the study’s second phase, we will involve professional teams from the industry. The planned studies and their contents are briefly discussed below.

Article 1: Systematic Literature Review (SLR)

The first planned study will focus on Research Question 1, analyzing the connection between individual well-being within teams and how it impacts the overall team performance and productivity.

SLR will be conducted to gather and analyze the relevant studies that examine the relationship between the well-being, performance, and productivity of individuals and how these aspects

influence the overall performance of teams. The first article offers an overview of the connection between well-being and performance along with the factors required for effective teamwork, and opportunities for more research. Additionally, it is expected to provide educational content for software engineering professionals from a variety of settings, including academia, and open source closed-source software projects.

Significant research questions about this study include:

- What methodologies have been used to assess individual well-being in software engineering?
- What kind of factors effects the individual well-being in hybrid development teams?
- How does the well-being of individual team members impact the overall performance of hybrid software development teams?

Article 2: Case Study 1

A case study on students of the LUT bachelor-level course “Capstone Project for Software and Systems Engineering”, working on real software projects from the Lahti campus in co-located mode will be conducted to analyze social debt in hybrid software development teams. The main aim of this study is to address Research Question 2 and to suggest improvements specific to the context. 360° webcam will be installed for each team to record their full panoramic view of non-verbal cues i.e., facial expressions, 3D gaze patterns, and head movements while teams will be conducting their daily scrum and sprint retrospective review meetings. Moreover, to record verbal cues or speech emotions, conference microphones will be installed along the webcams to record the audio while teams will discuss and share their progress and ideas in the daily scrum and retrospective meetings respectively. To analyze the recorded non-verbal data a novel machine learning-driven facial analysis system (FAS) developed by Gloor’s team will be used and to analyze verbal data best machine learning algorithm i.e., Shapley additive explanations (SHAP) will be utilized. Along with the verbal and non-verbal data, several online surveys including personality surveys, self-perceived performance, and prior relation performance will be conducted at the beginning and end of the case study while the PERMA+4 survey that covers the work-related well-being will be conducted daily. To collect and analyze the survey data Happimeter web app developed by Gloor’s team will be used, and the result of the survey will be reflected on participants immediately through virtual mirroring.

Article 3: Case Study 2

A case study on students of the LUT bachelor-level course “Capstone Project for Software and Systems Engineering”, working on real software projects from the Lappeenranta campus in hybrid mode will be conducted to analyze social debt in hybrid software development teams. The main aim of this study is to address Research Question 2 and to suggest improvements specific to the context. Teams in this case will mainly be working in a hybrid manner so to record the teams during their daily and retrospective meetings, different meeting tools (zoom Slack, Trello, and others) will be used. To analyze the recorded non-verbal data a novel machine learning-driven facial analysis system (FAS) developed by Gloor’s team will be used and to analyze verbal data best machine learning algorithm i.e., Shapley additive explanations (SHAP) will be utilized. Along with the verbal and non-verbal data, several online surveys including personality surveys, self-perceived performance, and prior relation performance will be conducted at the beginning and end of the case study while the PERMA+4 survey that covers the work-related well-being will be conducted daily. To collect and analyze the survey data Happimeter web app developed by Gloor’s team will be used, and the result of the survey will be reflected on participants immediately through virtual mirroring.

Article 4: Multiple Case Study

A multiple case study is planned to compare the results of the previous study among industry professionals by using the methods used in the prior study and to assess the effectiveness of the used approaches. Furthermore, to generalize the previous results among professional hybrid development teams and to implement the improvements suggested in the prior case study.

We will ensure that all the data collected from students and professionals get treated with confidentiality abiding by all the ethical regulations.

Table 2
Planned timeline

	Fall 2023	Spring 2024	Spring 2025	Fall 2025	Spring 2026	Fall 2026	Spring 2027
Article 1	Collection	Analysis					
Article 2		Collection	Analysis				
Article 3			Collection	Analysis			
Article 4				Collection	Analysis		
Dissertation						Finalizing	September 2027

4. Contributions

The expected contribution of this study are as follows:

- Highlight the importance of social aspects in development teams by emphasizing the need for a holistic approach that captures social aspects to improve productivity and job satisfaction.
- Provide the tools and practical guidelines to address social debt in software development.
- Provide insight into how AI-driven tools can be utilized effectively to monitor and improve team dynamics in virtual and hybrid settings.
- Increase the productivity and happiness of development teams by reducing social debt.

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