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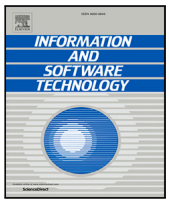

The impact of personality traits on scrum team effectiveness: Insights from Vietnamese software development companies

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ABSTRACT

Context: Scrum is the most popular methodology within Agile software development, but the internal dynamics of Scrum teams are not fully understood. As a new destination for software outsourcing, Vietnam widely uses the Scrum development method in its software development companies. This study investigates the impact of personality traits on Scrum team effectiveness in the Vietnamese software development industry.
Objectives: This research aims to identify the effects of personality on Scrum team effectiveness. We developed a survey based on the HEXACO personality model and the Agile Team Effectiveness Model (ATEM). This includes gathering and analysing data on the personality traits and Scrum team effectiveness of software development professionals in Vietnam, covering various roles beyond developers.
Methods: Our experimental study measures the personalities of team members based on the six HEXACO personality traits (extraversion, conscientiousness, agreeableness, openness to experience, emotionality, and honesty-humility) and team effectiveness using ATEM's three coordinating mechanisms (shared mental model, mutual trust, and communication). We used linear regression to verify the proposed hypotheses.
Results: With a sample size of 181 participants, five out of six personality traits influenced two of ATEM's coordinating mechanisms. Agreeableness and Conscientiousness positively impacted Shared Mental Models, while Extraversion and Emotionality affected Mutual Respect. Weaker relationships were found, but they lacked practical significance. The Honest-Humility trait did not influence effectiveness.
Conclusion: Our study shows that personality has relatively small effects on Scrum Team Effectiveness. Agreeableness and Conscientiousness have the most significant positive effects on Shared Mental Models, while Extraversion positively affects Mutual Respect, and Emotionality has a negative impact on Mutual Respect. In summary, Scrum teams benefit from members with high scores in Extraversion, Agreeableness, Conscientiousness, Openness to Experience, and low scores in Emotionality.

1. Introduction

The agile philosophy in software development emphasises principles of adaptability, iterative progress, and dynamic teamwork. This approach has proven highly beneficial for organisations, resulting in reduced time to market, increased predictability in project outcomes, and lower operational risks [1]. According to the 16th Annual State of Agile Report [1] over 80% of organisations reported using Agile methodologies or a combination of Agile methodologies and other approaches. Notably, Scrum has experienced rapid growth in recent years, with 87% of surveyed organisations – including those in technology, financial services, professional services, healthcare/pharma, government, industrial manufacturing, insurance, telecommunications, transportation, energy, retail, education, media and entertainment, non-profit, and other industries–currently implementing it [1].

Scrum embodies a collaborative and iterative approach to software development. In alignment with the principles outlined in the Agile Manifesto [2], which prioritises individuals and interactions over processes, Scrum places the development team and the interactions between team members at its core. Consequently, the essential skills and abilities of team members to work effectively together are imperative to the overall effectiveness and success of the Scrum framework.

Previous research in Agile and Scrum software development has often focused on topics like adoption strategies and critical success factors within the framework (See Section 2.3). Notably, the cohesiveness of the Scrum team has been recognised as a key influencer in shaping project outcomes [3]. Effective Scrum teams exhibit traits such as seamless communication, the harmonious utilisation of skills, and adaptability to various situations. This effectiveness is impacted by a

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combination of internal and external factors. Externally, it is widely accepted that Agile or Scrum teams benefit from increased autonomy, reducing interference from management during the development process [4]. Internally, team effectiveness depends on the attributes and abilities of individual team members [5].

In the field of management literature, substantial efforts have been dedicated to studying how to foster high-performance teams [6–13]. Specific subjects include leadership theory, team composition, roles within the team, and the influence of individual team member characteristics on team interactions. Personality is one such extensively studied characteristic, with some organisations using personality tests in their recruitment processes. Common tests include the Myers-Briggs Type Indicator (MBTI) [14], the Big Five Inventory (BFI) [15], and the Five-Factor Model (FFM) [15]. While the MBTI has faced criticism for its lack of academic rigour [16,17], the BFI/FFM are more empirically grounded and suitable for both practical application and academic research. A newer model, HEXACO, has gained traction as it addresses some BFI/FFM limitations and offers a similar framework with its six traits: Extraversion, Conscientiousness, Agreeableness, Openness to Experience, Emotionality, and Honest-Humility. Our study is based upon this HEXACO model.

The current literature on Scrum team effectiveness is limited, with most research focusing on Agile teams in a broader context [18,19]. While Agile and Scrum teams share many similarities, Scrum is a distinct framework within Agile, marked by key differences in structure and flexibility. Scrum teams follow a clearly defined framework with specific roles, events, and artefacts, whereas Agile teams have more flexibility, allowing for varied implementations [20,21].

Psychological safety, a critical enabler of agile team effectiveness, fosters open communication and trust [22]. However, the role of individual personality traits in cultivating such safety within Scrum teams remains underexplored [19], particularly in emerging markets like Vietnam.

Scrum teams manage work through fixed, time-boxed iterations known as sprints, typically lasting 1–4 weeks, and are required to hold specific events such as Sprint Planning, Daily Standups, Sprint Reviews, and Sprint Retrospectives. In contrast, Agile teams have the freedom to structure their work and meetings in more adaptable ways, tailored to their unique needs [20,21]. In this work we are interested in mature Scrum teams. We define a mature Scrum team as a team where most members are experienced in using Scrum to coordinate their activities.

Despite the prevalence of Scrum in practice, there is little specific research on Scrum team effectiveness. To address this gap, we propose adapting models from studies on Agile teams. The Agile Team Effectiveness Model (ATEM) [18] provides a strong foundation, as it is empirically validated. In this paper, we focus on three of ATEM's coordinating mechanisms – Shared Mental Models, Mutual Respect, and Communication – within the broader framework of team effectiveness.

Our research focuses on how individual characteristics, notably personality, impact the effectiveness of mature Scrum-based software development teams. Previous studies often rely on personality assessment tools such as MBTI or BFI/FFM, which have faced criticism regarding their validity. The absence of a formal definition for "Scrum Team Effectiveness" in the literature further underscores this knowledge gap. Consequently, there is a need to investigate the influence of personality on the effectiveness of Scrum teams.

To address this gap, to enable improved scrum team composition, our research explores how individual personality traits impact the effectiveness of Scrum teams in software development companies in Vietnam. To do this we performed a survey of software developers, mainly working for 5 prominent software companies in Vietnam, mainly working on contract work or tailor made software. The work of these organisations is project based, with some project teams split up into smaller teams, and others executed by single teams. By forming hypotheses and developing research instruments, we aim to answer the following research question:

What are the effects of personality traits on the effectiveness of Scrum teams in Vietnam's mature software companies?

Our specific objectives are as follows:

- Develop a survey by adapting existing research on personality, particularly utilising the HEXACO model, and Scrum Team Effectiveness, with a focus on the Agile Team Effectiveness Model (ATEM).
- Gather and analyse data related to the personality traits and Scrum team effectiveness of software development professionals in Vietnam, encompassing various roles beyond developers.
- Identify the precise impact of personality on mature Scrum team effectiveness within the specific context of the Vietnamese software development industry.

The findings of this paper focus on the Scrum development process, highlighting how personality traits such as extraversion, agreeableness, conscientiousness, and openness can enhance the formation of more effective software development teams situated in mature organisations. This insight can guide team managers in forming teams based on members' personalities or by fostering group dynamics to resolve conflicts and strengthen cohesion, ultimately creating a better team environment and improving overall performance.

We have organised this work as follows. Initially, we address the necessity for studying the impact of personality traits on Scrum team effectiveness. We review various personality models, delve into personality research within software engineering, and explore topics related to Scrum team effectiveness based on existing literature in Section 2. Subsequently, we present the research model and hypotheses in Section 3, followed by a description of the methods employed in Section 4. Finally, we discuss the obtained results in Section 5, highlighting both theoretical and potential managerial implications in Section 6, and address research limitations in Section 6.2 and potential avenues for future work in Section 7.

2. Related work

The related work is reviewed in three distinct areas. Section 2.1 introduces the Myers-Briggs Type Indicator (MBTI), Big Five Inventory (BFI), Five Factor Model (FFM), and HEXACO model of personality. Section 2.2 examines how the Big Five Inventory (BFI) or the Five Factor Model (FFM) has been shown to significantly impact various aspects of software development professionals, as well as the effectiveness, productivity, and product quality of software development teams. Section 2.3 explores the research on the relationship between Scrum and teams, delving into both the broader context and specific variations.

2.1. Personality models

Personality traits are widely acknowledged to have a significant influence on human behaviour, reflecting a degree of consistency that aligns with these traits [23]. Researchers in psychology have sought to quantify personality using various models, with many focusing on trait models. These models divide personality into distinct dimensions or sets of traits, shedding light on how individuals feel, think, and behave, offering testability, predictive capabilities, and some degree of behavioural stability [24]. Commonly, personality traits are assessed through psychometric tests, often employing self-report questionnaires that capture underlying, context-independent behavioural patterns. Table 1 summarises the key characteristics, uses, and criticisms of the aforementioned personality models, highlighting their differences in dimensions, validity and predictive capability, cultural applicability, usage, generalisability, major criticisms, and research focus.

One such assessment, the Myers-Briggs Type Indicator (MBTI), dating back to the 1940s, categorises personality into four dimensions

Table 1
Differences among the personality models.

Models	No. of Dims	Dimensions (Dims)	Validity and reliability	Predictive capability	Usage	Cultural generalisability	Major criticisms	Research focus
Myers-Briggs Type Indicator (MBTI)	4	Extraversion/ Introversion, Sensing/Intuition, Thinking/Feeling, Judging/Perceiving	Criticised for low validity and reliability [16,17]	Limited due to categorical nature	Personal development, career counselling	Limited, primarily based on Western populations	Lacks empirical support, dichotomous nature limits nuance [16,17]	Less used in rigorous research
Big Five Inventory (BFI) or Five Factor Model (FFM)	5	Openness to Experience, Conscientiousness, Extraversion, Agreeableness, Neuroticism	Considered more reliable and consistent across contexts [15,25,26]	Moderate, used extensively in organisational research	Widely used in research for understanding personality across various domains	Moderate, developed primarily in Western cultures	Limited predictive and explanatory power [11,25]	Widely used, particularly in studies on workplace behaviour, team dynamics
HEXACO model	6	Honesty-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, Openness to Experience	High reliability, greater cultural generalisability [27,28]	Expanded predictive capability due to additional factor of Honesty-Humility [27]	Addresses some limitations of BFI, includes sixth factor for more comprehensive personality understanding	Higher, due to inclusion of diverse languages and cultures [28]	Some overlap with BFI traits, but offers additional dimension for a more nuanced view.	Increasingly popular in research, especially in personality and work-related behaviours [29–32].

(Extraversion/Introversion, Sensing/Intuition, Thinking/Feeling, and Judging/Perceiving) and is widely used but criticised for issues with validity and reliability [16,17]. In response to these challenges, the "Big Five Inventory" (BFI) was developed based on lexical analysis and factor analysis, identifying five factors: Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. The BFI is held in higher regard than the MBTI due to its consistency across various contexts but is criticised for its predictive and explanatory limitations [25]. Despite criticisms, the BFI is widely employed in organisational research, with applications in explaining workplace behaviour, performance, team dynamics, and more. Another variant, the Five Factor Model (FFM), mirrors the BFI's attributes and five dimensions [15].

The HEXACO model of personality has gained prominence as a viable alternative to the BFI, addressing some of its limitations [27]. Notably, the HEXACO model recognises the potential presence of a sixth personality factor, offering a more comprehensive and nuanced understanding of personality traits [27]. This expansion to a sixth factor results from a broader lexical analysis that encompasses a diverse range of cultures and languages, indicating greater generalisability across different cultural contexts and enhancing its descriptions of personality traits [28]. The HEXACO model is widely utilised in contemporary research, particularly in the examination of how personality traits influence work-related behaviours [29–31]. The HEXACO dimensions, while similar to those in the BFI, exhibit some distinctions: Honest-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, and Openness to Experience. Given the established reliability of the HEXACO model, this study employs its six factors as predictors of effective behaviour within Scrum teams in software development.

Furthermore, it is worth noting that within a team context, individual team members' personalities are shaped by the team environment, while the team environment is influenced by individual personalities [33,34]. These studies emphasise that the interactions among team members give rise to a unique "team personality", which is essentially a blend of individual member personalities and the team's environment. However, this team personality is still typically described using the trait-based approach. Alternative methods of describing personality, such as the Behaviourism approach, where an individual's personality is viewed as a learned response to external conditions, and the Personal Construct approach, which posits that personality is formed by an individual's mental model for conceptualising their environment [35], have been proposed. Nonetheless, these approaches heavily depend on the intricacies of the external environment, making them less testable in real-world contexts, and as a result, they are less commonly utilised in research outside of pure psychology.

2.2. Personality research in software engineering

The intricate realm of software development places a spotlight on the profound influence of an individual's personality, uniqueness, and identity on the overall success of development projects, often an aspect overlooked. The combined interplay of personality traits and communication styles significantly shapes the organisation's productivity. These complex factors intricately affect individual interactions, collaborations, and engagement in both individual and team tasks [36].

Within the realm of software engineering, the Myers-Briggs Type Indicator (MBTI) has been employed to propose role assignments, associating specific personality types with various roles like developers, testers, project managers, and more [37–39]. It is observed that personality, particularly the Judging types, significantly influences an individual programmer's performance and efficiency [40]. For software teams, the Extraversion/Introversion dimension affects team formation schemes and, consequently, performance [41]. Research also suggests that the composition of personality types can impact the formation of effective software teams, highlighting the importance of balancing Sensing/Intuition, Thinking/Feeling, and a higher number of Extraverts [9]. In the context of Agile Software Development, where people take precedence over processes, team members' personalities play a pivotal role in determining teamwork effectiveness and results [42].

While the MBTI has been the primary tool for assessing personality in software engineering research, recent questions have been raised regarding its validity and reliability. Consequently, more researchers are turning to the Big Five Inventory (BFI) and the Five Factor Model (FFM) as alternatives [10,43]. Barrick et al. demonstrated a direct link between all five FFM traits and performance in various fields, with conscientiousness and agreeableness emerging as pivotal factors influencing team performance [33,43]. Developers with higher Agreeableness and Conscientiousness scores tend to engage in collaborative efforts and contribute effectively to projects. Those with high Openness to Experience scores exhibit creativity and emotional awareness, applying innovative thinking to problem-solving tasks [8]. This extends to various roles in software development, such as requirements analysts, who display higher efficiency with elevated scores in Openness to Experience, Extraversion, and Conscientiousness [12,44].

Researchers also explore how individual BFI traits impact performance and adaptability within specific software development roles [45]. In the realm of Agile methodologies, individuals with high Extraversion and Openness to Experience tend to favour agile practices,

while lower levels of extraversion can pose challenges for active participation required by Agile processes, particularly in the Scrum framework [6]. Teams less exposed to clients tend to have individuals with lower Extraversion scores, whereas a balanced mix of Sensing/Intuition and Thinking/Feeling types alongside a higher number of Extraverts results in more effective Agile teams [46]. Agreeableness and Extraversion emerge as essential traits for team effectiveness, while other FFM dimensions also play a vital role [47]. Conscientiousness alone influences "Agile" tendencies, with even greater effects when combined with high Agreeableness, Openness to Experience, and low Neuroticism [48]. Teams with high Agreeableness scores foster trust, cooperation, and mutual respect, while those with higher Openness to Experience support innovation and effective problem-solving [7].

The importance of various personality traits varies across different stages of the software development life cycle. In the analysis and design phase, higher levels of Conscientiousness and Agreeableness result in superior designs and enhanced productivity. During the implementation stage, Conscientiousness, Openness to Experience, and Agreeableness contribute to high-quality code. In the testing phase, teams characterised by high Conscientiousness and Agreeableness also perform better [11].

In conclusion, the Big Five Inventory (BFI) or the Five Factor Model (FFM) has been found to have a significant impact on various aspects of software development professionals, as well as on the effectiveness, productivity, and product quality of software development teams.

2.3. Scrum team effectiveness

Strode et al. [18] provide a comprehensive review of teams, team effectiveness, and teamwork effectiveness models in the context of agile teams. Similarly, research Verwijs and Russo [13] offer an extensive examination of how different roles within Scrum teams influence team effectiveness. In this section, we focus specifically on Scrum team effectiveness models, exploring their components and mechanisms from a more critical perspective.

Tam et al. [5] revealed that team capabilities – and subsequently, the success of Agile projects – are primarily influenced by internal factors, such as team characteristics, individual member attributes, and team processes. In contrast, external factors like organisational support or project-specific characteristics were found to have less impact on team capabilities and project outcomes. These findings were partially echoed in a study of 40 Scrum teams by Kelle et al. [49], further emphasising the internal dynamics of the team.

Scrum is often associated with the concept of effective, self-managing teams. This means it is not directly suitable for projects that require multiple teams to collaborate [50] – leading to adaptations such as SAFe (Scaled Agile Framework) [51,52], LeSS (Large-Scale Scrum) [53], and Scrum@Scale [54], that adapt team dynamics. It should be noted that it is the size of the project, not the organisation size that determines whether these adaptations are needed. Larger organisations have the advantage of having more maturity in their (Scrum) team organisation.

Much of the research on team-level factors has sought to understand the dynamics that contribute to such teams' effectiveness. For instance, a qualitative study identified desirable personality traits crucial for the formation and operation of effective Scrum teams [45]. However, the literature lacks a clear and consistent definition of Scrum team effectiveness. Despite an increasing body of research on Agile teams, there is still no comprehensive or specific model defining effectiveness exclusively for Scrum teams. While several models have been proposed to explain effectiveness factors for Agile teams in general [18], they have yet to be tailored specifically to Scrum teams.

Salas et al. [32] introduced the Big Five teamwork model, which distinguishes between team effectiveness and team performance. This model, grounded in literature and widely accepted in Agile research, has been highly influential. According to Salas, team performance refers to the outcomes a team achieves – such as meeting project goals, adhering to budgets and schedules, and delivering high-quality software [55] – while team effectiveness pertains to the interactions and dynamics within the team during task execution. Moe et al. [56] successfully applied Salas' model to Scrum teams, exploring how its components influenced team success.

More recently, Verwijs and Russo [13] adapted Salas' model in their study of Scrum team effectiveness. However, their research went beyond internal team dynamics and investigated external factors that influence effectiveness, such as organisational context, stakeholder engagement, customer demands, and technological landscapes. This shift highlights the increasing need to consider both internal and external influences on Scrum teams.

Despite these contributions, literature specifically focused on Scrum team effectiveness remains sparse. Consequently, it is necessary to look at Agile teams more broadly. A notable example is the Agile Teamwork Effectiveness Model (ATEM) proposed in [18]. This model builds upon Salas' Big Five model but tailors it to Agile teams, identifying five key components (shared leadership, peer feedback, redundancy, adaptability, and team orientation) and three coordinating mechanisms (mutual trust, shared mental models, and closed-loop communication).

Salas et al. [32] originally emphasised the importance of coordinating mechanisms in determining team success. In ATEM, these mechanisms are: (1) Shared Mental Models, where team members share a common understanding of project goals, tasks, processes, and the product itself; (2) Mutual Trust, demonstrated by respect, openness, and positive social climate among team members; and (3) Communication, determined by factors such as colocation, openness, supporting infrastructure, and team atmosphere.

Interestingly, Verwijs and Russo [13] found that, while external factors influenced effectiveness, the coordinating mechanisms identified in Salas' model were strong predictors of Scrum team success. However, there was no significant support for the predictive power of the specific components in Salas' model. This suggests that when measuring Scrum team effectiveness, it is more critical to focus on coordinating mechanisms, rather than on individual components.

Psychological safety, defined as a team's shared belief that members can take interpersonal risks without fear of negative consequences, is a critical driver of Scrum team effectiveness [22]. In their qualitative study of agile teams, Alami et al. [22] identified individual-level antecedents, such as empathy and openness, which align with personality traits like Agreeableness and Openness to Experience [15]. These traits foster collaborative practices, such as effective communication and mutual respect, which are essential for Scrum's self-managing teams [56]. In the context of this study, psychological safety may mediate the relationship between personality traits and team effectiveness, particularly through mechanisms like Shared Mental Models and Mutual Respect. For instance, Agreeableness, characterised by empathy and cooperation, may enhance psychological safety, enabling team members to align cognitively and build trust. This study extends prior work by quantitatively examining how personality traits influence these dynamics in Vietnamese Scrum teams.

In this section, we delve into various personality models in Section 2.2, exploring personality research across different realms of software engineering in Section 2.2. We have chosen to adopt the HEXACO personality model for our research. Section 2.3 reviews the research on Scrum team effectiveness, where, drawing from existing studies, we incorporate the Agile Team Effectiveness Model (ATEM) into our research. The following section outlines our research framework and hypotheses, aligning with both the HEXACO personality model and the Agile Team Effectiveness Model (ATEM).

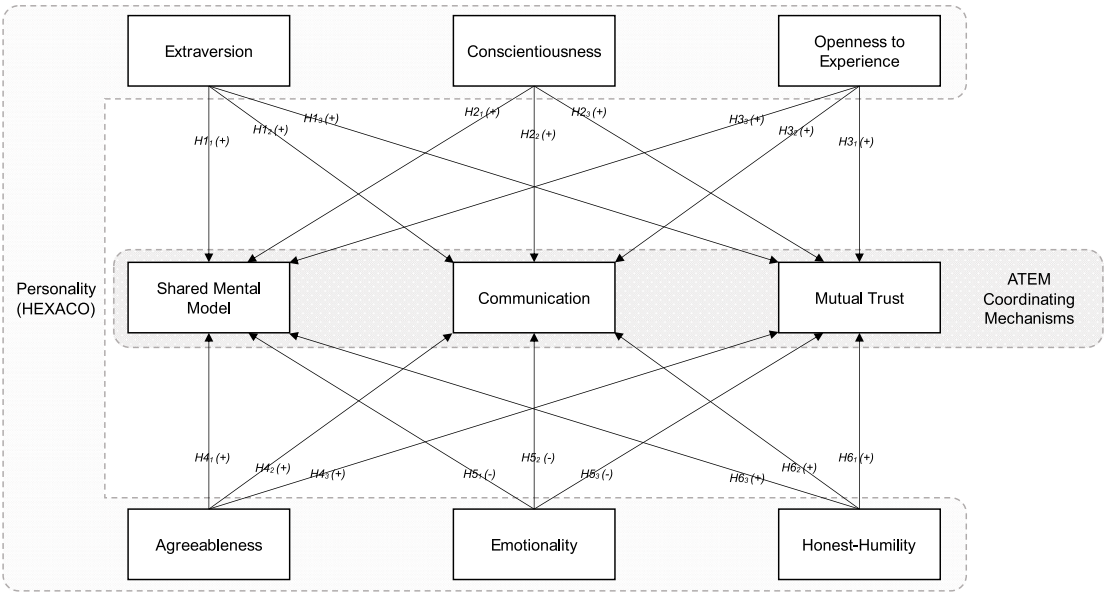

Fig. 1. Research Framework.

3. Research framework and hypotheses

The main objective of this study is to investigate how personality traits, as defined by the HEXACO model [27,57], impact the effectiveness of Scrum software development teams. The six personality dimensions outlined in the HEXACO model [27,57] are considered as independent variables, while the three coordinating mechanisms proposed by the Agile Team Effectiveness Model (ATEM) [18] serve as dependent variables.

Six key hypotheses are formulated to investigate the associations between the six personality traits outlined in the HEXACO model and the three coordinating mechanisms proposed by the ATEM. The personality traits considered are Extraversion, Conscientiousness, Agreeableness, Openness to Experience, Emotionality, and Honesty-Humility from the HEXACO model [27,57]. The coordinating mechanisms under examination are Shared Mental Model, Mutual Trust, and Communication from the ATEM [18]. The research model, including all hypotheses, is summarised in Fig. 1.

The first hypothesis focuses on Extraversion, which relates to an individual's outgoing nature, self-confidence, and willingness to lead or engage with groups [41]. Those with high extraversion scores tend to excel in social interactions, finding enjoyment and experiencing positive emotions in such settings [29–31]. Several studies [6,12,44,45,47,58] have supported the notion that extraverted individuals in Agile teams are more likely to be engaged with their work, derive higher job satisfaction, and contribute significantly to the success of their teams.

- Hypothesis 1 (H1): There is a positive association between Extraversion and the coordinating mechanisms determining Scrum team success.
  - $H1_1$: Extraversion is positively associated with Shared Mental Models.
  - $H1_2$: Extraversion is positively associated with Mutual Trust.
  - $H1_3$: Extraversion is positively associated with Communication.

Conscientiousness, as a personality trait, signifies an individual's ability to effectively manage their time, maintain an organised environment, demonstrate discipline in achieving goals, pursue accuracy and perfection in their work, and employ a thoughtful and deliberate approach to decision-making [12,44]. Numerous studies have underlined the significance of individuals with high conscientiousness in the software development process [11,12,27,33,44–46,48,59]. Teams with higher overall scores in this personality trait exhibit improved performance, engage in more collaborative efforts, and experience fewer instances of counterproductive behaviours.

- Hypothesis 2 (H2): There is a positive association between Conscientiousness and the coordinating mechanisms determining Scrum team success.
  - $H2_1$: Conscientiousness is positively associated with Shared Mental Models.
  - $H2_2$: Conscientiousness is positively associated with Mutual Trust.
  - $H2_3$: Conscientiousness is positively associated with Communication.

Agreeableness within the HEXACO framework gauges an individual's capacity to be tolerant in judging others, their willingness to compromise and cooperate with peers, and their ability to effectively manage their temper [27]. It is worth noting that this trait includes temperament, which is associated with the Neuroticism trait in the BFI or FFM [60]. Therefore, the effects observed for Neuroticism in previous studies using the BFI or FFM should also be interpreted as effects of the Agreeableness trait in the HEXACO [61]. Several studies [7,11,44–46,48] have demonstrated that Agreeableness significantly influences the productivity and collaborative dynamics of Agile teams.

- Hypothesis 3 (H3): There is a positive association between Agreeableness and the coordinating mechanisms determining Scrum team success.
  - $H3_1$: Agreeableness is positively associated with Shared Mental Models.
  - $H3_2$: Agreeableness is positively associated with Mutual Trust.
  - $H3_3$: Agreeableness is positively associated with Communication.

Individuals scoring higher on the Openness to Experience scale tend to show greater interest in art and nature, possess curiosity across diverse knowledge domains, exhibit a creative imagination, and are more inclined towards exploring unconventional ideas and engaging with others [7]. Numerous studies [7,8,11,12,44,45,48,58] support the idea that individuals with high Openness to Experience scores tend to be more innovative in their work and hold more favourable opinions of Agile practices .

- Hypothesis 4 (H4): There is a positive association between Openness to Experience and the coordinating mechanisms determining Scrum team success.
  - $H4_1$: Openness to Experience is positively associated with Shared Mental Models.
  - $H4_2$: Openness to Experience is positively associated with Mutual Trust.
  - $H4_3$: Openness to Experience is positively associated with Communication.

High Emotionality in an individual is often linked to a higher likelihood of experiencing anxiety in stressful situations, a greater need for emotional support, increased empathy, and stronger emotional attachments to others [27]. It is worth noting that this trait in the HEXACO model is most closely related to the Neuroticism trait in the BFI or FFM [60]. Previous research [45,48,58] has indicated that lower Neuroticism, as described in the BFI or FFM, is associated with a stronger preference for Agile methods, and software teams have expressed a preference for working with individuals who have lower Neuroticism scores.

- Hypothesis 5 (H5): There is a negative association between Emotionality and the coordinating mechanisms determining Scrum team success.
  - $H5_1$: Emotionality is negatively associated with Shared Mental Models.
  - $H5_2$: Emotionality is negatively associated with Mutual Trust.
  - $H5_3$: Emotionality is negatively associated with Communication.

Individuals with high Honesty-Humility scores tend to avoid manipulation for personal gain, resist rule-breaking behaviours, and have little interest in excessive wealth or social status [27]. However, research on the Honest-Humility dimension within the context of software development remains limited. Only one study has shown a positive relationship between higher Honest-Humility scores and software team performance [62]. Although evidence for the effect of this trait is limited, the authors of the HEXACO have noted that Honest-Humility is negatively associated with antisocial and counterproductive teamwork behaviour [28].

- Hypothesis 6 (H6): There is a positive association between Honest-Humility and the coordinating mechanisms determining Scrum team success.
  - $H6_1$: Honest-Humility is positively associated with Shared Mental Models.
  - $H6_2$: Honest-Humility is positively associated with Mutual Trust.
  - $H6_3$: Honest-Humility is positively associated with Communication.

4. Research methodology

This research adopted a quantitative approach, utilising surveys to collect data from a selected sample of software development professionals. In Vietnam, the software development workforce is estimated to be around 1,000,000 individuals [63]. While the exact proportion of software professionals employing Scrum in Vietnam is not officially recorded, a global estimate suggests that approximately 80% of software development teams worldwide utilise Scrum [1]. Considering this estimate, it can be inferred that about 800,000 professionals in Vietnam work with the Scrum methodology in their projects. To determine the appropriate sample size, standard methods were applied [64]. Assuming a confidence level of 95%, a margin of error of 8%, and a standard deviation of 0.5, the sample size for a population of approximately 800,000 is calculated to be 151. If the margin of error is reduced to 7%, the sample size should increase to 196. Consequently, the survey aimed to gather responses from more than 150 participants to achieve a margin of error between 7% and 8%.

4.1. Measurement

The measurement items used in this study draw from existing literature on personality and team effectiveness in Agile methodologies. The measurement of personality is adopted from the six traits from the HEXACO model [27,57] and the measurement of the team effectiveness is adopted from ATEM [18]. All items can be found from Appendix Tables A.11 and A.12. The research focused on individuals within five prominent Vietnamese software development companies actively participating as team members in Agile software development projects within Scrum teams.

4.2. Data

This research used an online survey to collect the necessary data. The survey was primarily directed to employees of five prominent software development companies in Vietnam, although participants from other companies were not excluded (based upon the reported company profiles this amount is likely low). The questionnaire was developed in English and subsequently translated to Vietnamese by the first author (Available as auxiliary material). The survey questions employed a 5-point Likert scale, ranging from “Strongly Agree” to “Strongly Disagree”. The survey was hosted on the JISC platform as recommended for university ethics approval (including data protection). Subsequently, it was shared with contacts within five prominent Vietnamese software development companies, who further disseminated it to software professionals.

While our sample includes larger teams (12–14 members), studies like Alami et al. [22] demonstrate that psychological safety, a driver of agile team effectiveness, operates in diverse agile contexts, supporting the relevance of our findings to real-world Scrum practices.

181 responses were received. Considering the characteristics of our sample, the distribution of participants across different age groups in Table 2, highlights that the majority are under 32 years old, with the largest group falling between 23 and 27. No participants were over 42 years old. The identical group sizes between age categories and years of experience suggests that most software development professionals in Vietnam commence their careers at a young age. However, it is crucial to note that this was a convenience sample, and participants likely belonged to one of the five specific companies. Therefore, the age distribution might be influenced by the age preferences of these companies in their recruitment and their requirement for Agile development — limiting the reliability of the study for contexts that are fundamentally different. We also remind readers that this study looks at the Vietnamese context and cultural factors are likely to play a role.

Examining the educational backgrounds of participants reveals that the majority hold a Bachelor’s degree in Table 2. Notably, a small fraction possessed a Master’s degree, and none held a doctorate. Surprisingly, a substantial number of participants had only a high school diploma or its equivalent. This could be attributed to software development companies frequently recruiting developers directly from universities, possibly including undergraduates who had not yet completed their degrees. The term “vocational training” encompasses institutions providing programming certificates, such as coding bootcamps.

Analysing the size of the companies where participants are employed, most are medium to large companies, defined as having over 500 employees in Table 2. The majority work in companies with over 1000 employees. Regarding the average duration of development

Table 2
Demographic data.

Age Group (PAG)	*N*	%	Agile experience(EDU)/Software development experience (ESD)	*N*	%	Education(EDU)	*N*	%
18–22	37	20.4	<1 year	37	20.4	High school	26	14.4
23–27	65	35.9	1–3 years	65	35.9	Vocational training	14	7.7
28–32	38	21.0	3–5 years	38	21.0	Associates	17	9.4
33–37	25	13.8	5–10 years	25	13.8	Bachelor	105	58.0
38–42	16	8.8	>10 years	16	8.8	Master	19	10.5
–	–	–	–	–	–	PhD	0	0
Company size (CSZ)	*N*	%	Average project length (APL)	*N*	%	Team size (TSZ)	*N*	%
500–1000 people	39	21.5	6–12 months	110	60.8	6–8 people	14	7.7
1000–1500 people	71	39.2	18–24 months	36	19.9	9–11 people	62	34.3
1500–2000 people	71	39.2	12–18months	35	19.3	12–14 people	105	58.0
Role in team (CTR)	*N*	%	Types of software developed (CSS)	*N*	%	Industry served (CID)	*N*	%
Scrum master	4	2.2	Enterprise software	101	22.0	Wholesale and retail	105	10.2
Project manager	20	11.0	Embedded software	34	7.4	Utilities	41	4.0
Product owner	10	5.5	Custom-made software	96	20.9	Telecommunications	39	3.8
Business analyst	23	12.7	Mobile apps	90	19.6	Medical services	142	13.7
Designer	3	1.7	Large software systems	35	7.6	Manufacturing	101	9.8
Tester	38	21.0	Web development	103	22.4	IT	142	13.7
Developer	83	45.9	Others	0	0	Hotels or food	175	16.9
–	–	–	–	–	–	Government or public administration	107	10.3
–	–	–	–	–	–	Banking and finance services	143	13.8
–	–	–	–	–	–	Defence or military	39	3.8

projects, it ranges from 6 months to 2 years, with 61% having projects lasting under 1 year. The majority of teams consist of 12 to 14 people (58%), followed by 9 to 11 people (34%), and 6 to 8 people (8%). Interestingly, this data suggests that most teams in the sample had more than nine members, potentially posing challenges related to team relationships, a topic for future research. It is worth exploring whether team size is dictated by team members or determined by management, as this aspect could confound results related to team effectiveness. Notably, management interference has been observed to hinder the efficiency of Scrum teams.

Examining participants' current roles or job titles reveals that the majority identify as developers, followed by testers, constituting more than half of the participant pool. Participants were also asked about the types of software their companies developed and the industries they served. 43.6% of the respondents had at least 3 years experience with agile/Scrum, and only 20.4% less than 1 year — this implies that there is a good amount of experience available in the sampled teams (in line with the overall composition in the population), making teams that would not class as mature Scrum teams unlikely.

While the data mainly represents a cross-section of five companies, participants' answers did not neatly align with exactly five distinct categories. The open-source option in the question on the software developed by their employer was not selected by any of the respondents. The employers were stated to develop average 2.5 different kinds of software — the most popular software kinds are enterprise software, custom-made software, and development services.

All companies were classified as outsourcing companies, producing software for other businesses or clients, with only two having their own proprietary products. In terms of industry served, the on average, the respondents identified 5.7 fields (out of 10) as covered by their employer — primarily in "Hotels or Food", potentially associated with POS (Point of Sale) software. Additionally, three out of the five companies had government contracts, explaining the high number of participants indicating "Government or Public Administration" and "Defence or Military". In some industries, there were no counts, indicating no representation from participants in those sectors. While the companies use larger project teams with sub-teams for some projects, this is limited to 60 employees for one and 40 for two others. Additional details have been provided in Table 2.

4.3. Data analysis method

This study used linear regression to formulate models that could verify the proposed hypotheses. SPSS is used to present and descriptively analyse the data for the control, independent, and dependent variables.

1. This study considers various control variables, encompassing demographic details mentioned in Table 2 such as age, gender, education, and experience. following recommendations made by Pletzer et al. [31].
2. Validity and reliability tests was conducted for both the independent and dependent variables. The following are the detailed steps:
    - Independent variables: Exploratory Factor Analysis (EFA) with the Principal Component method [65] is utilised to assess the validity of the six independent dimensions proposed by the HEXACO theoretical framework. The Kaiser–Meier–Olkin statistic and Barlett's test of Sphericity [66, 67] are used to examine the suitability of EFA.
    - Dependent variables: As this part of the survey is newly designed based on the theoretical foundations of the ATEM [18], the validity of the dependent variables is explored to identify latent variables discovered during the study.
3. Identifying independent scales and assessing reliability: The loading results from the EFA are used to identify independent scales. Cronbach's alpha is used to assess the reliability of each scale, and adjustments are made as necessary (i.e., removing items if the reliability statistic is below adequate).
4. Aggregating variables: The variables are aggregated by calculating the means of each scale.
5. Producing a correlation matrix: A correlation matrix is produced to investigate potential correlations between the control, independent, and dependent variables. This guides the suitability of employing linear regression.
6. Applying linear regression: Linear regression is applied to test the formulated hypotheses. Models are tested for covariance to ensure there are no effects of multicollinearity.

Table 3
Reliability statistics for independent variables.

Latent variable	Cronbach's alpha	Cronbach's alpha on standardised items	Item	Cronbach's alpha if item deleted
Openness to experience (OEX)	.916	.919	OEX2	.926
			OEX3	.837
			OEX4	.860
Conscientiousness (CON)	.918	.922	CON2	.924
			CON3	.889
			CON4	.818
Agreeableness (AGR)	.919	.922	AGR2	.909
			AGR3	.907
			AGR4	.825
Extraversion (EXT)	.895	.897	EXT2	.875
			EXT3	.841
			EXT4	.772
Emotionality (EMO)	.854	.857	EMO2	.762
			EMO3	.939
			EMO4	.653
Honest-Humility (HHM)	.792	.796	HHM1	N/A
			HHM3	N/A

Table 4
Reliability statistics for dependent variables.

ATEM Coord. Mech.	Latent variable	α	α−stdsd	Item	α−deleted
Shared mental models	Goal Orientation (GOR)	.651	.655	Common Understanding of Goals 1 (CUG1)	.320
				Common Understanding of Goals 1(CUG2)	.627
				Common Understanding the Product 1 (CUP1)	.678
	Understanding of Work (UOW)	.569	.569	Common Understanding of the Process 1 (CUW1)	.441
				Common Understanding of the Process 2 (CUW2)	.541
				Common Understanding the Product 2 (CUP2)	.522
				Common Understanding of Tasks (CUT2)	.479
Mutual trust	Respect for Teammates (RFT)	.638	.642	Respect 1 (RSP1)	.520
				Conflict 1 (CFL1)	.601
				Conflict 2 (CFL2)	.603
				Openness (OPN1)	.627
				Openness (OPN2)	.569
	Team Atmosphere (TAT)	.677	.680	Co-location 1 (COL1)	.573
				Co-location 2 (COL2)	.599
				Friendly Atmosphere 1 (FRN1)	.634
				Friendly Atmosphere 2 (FRN2)	.640
Communication	Social Climate (SCL)	.482	.483	SCL1	N/A
				SCL2	N/A

5. Results

After Gathering the data, we performed the analysis using linear regression model to verify the proposed hypotheses in Section 3. SPSS was used to present and descriptively analyse the data for the control, independent, and dependent variables. To identify latent variables and confirm the theoretical framework's adequacy, Exploratory Factor Analysis (EFA) was employed. Specifically, the Principal Component method with Varimax rotation was utilised to discover factor loadings for components. The initial attempt to use EFA with the PCA method for the independent variables produced suboptimal results, thus instead the Kaiser–Meyer–Olkin (KMO) test [67] was used to determine suitability of factor analysis. This approach, relies on the Kaiser-Guttman rule (based on eigenvalues ≥ 1) for extracting components.

5.1. Measurement model

Reliability tests using Cronbach's alpha were performed for each scale to check consistency. It shows that Cronbach's alphas were generally higher for the independent variables in Table 3 than the dependent variables in Table 4. This was expected as HEXACO items have a prior research background, while ATEM questions are newly developed and less rigorously validated. Importantly, social climate (SCL) in Table 4 had an unacceptable Cronbach's alpha of .482, leading to its exclusion from further analysis.

5.2. Test of hypotheses

5.2.1. Correlation matrix

As an initial step to assess regression model fit, a correlation matrix was generated for all numeric variables in Fig. 2. The highlighted area indicates the correlation between the independent and dependent variables. Additional noteworthy correlations were observed:

- A direct mapping between the participant counts in age groups (PAG) and years of experience in software development (ESD), revealing a sample comprised of individuals dedicated to software engineering professions.
- A weak but significant correlation (.267) between openness to experience (OEX) and Education level (EDU).
- A strong correlation (.802) between average project length (APL) and company size (CSZ), suggesting that development team size is linked to project duration.
- A weak but significant (.148) correlation between openness to experience (OEX) and company size (CSZ).
- Weak but significant correlations among some dependent variables (.230 between goal orientation (GOR) and understanding of work (UOW); .164 between respect for teammates (RFT) and team atmosphere (TAT)).

Pearson Correlations

	PGI	PAG	EDU	ESD	EAS	CSZ	APL	CTR	TSZ	OEX	AGR	CON	EXT	EMO	HHM	GOR	UOW	RFT	TAT
PGI																			
PAG	0.083																		
EDU	0.043	0.045																	
ESD	0.083	1.000**	0.045																
EAS	0.083	1.000**	0.045	1.000**															
CSZ	-0.059	0.108	-0.019	0.108	0.108														
APL	-0.049	0.094	-0.043	0.094	0.094	.802**													
CTR	-0.006	-0.067	-0.014	-0.067	-0.067	0.083	0.049												
TSZ	0.033	-0.024	-0.080	-0.024	-0.024	0.060	0.039	0.144											
OEX	-0.003	0.011	.267**	0.011	0.011	0.028	-0.054	0.065	.148*										
AGR	-0.004	-0.099	0.017	-0.099	-0.099	-0.135	-0.110	0.028	-0.040	-0.019									
CON	-0.057	0.030	0.057	0.030	0.030	0.026	-0.044	0.077	-0.092	-0.036	-0.085								
EXT	-0.009	-0.046	-0.123	-0.046	-0.046	-0.060	-0.032	-0.132	0.039	-0.025	0.042	-0.052							
EMO	0.070	-0.049	-0.050	-0.049	-0.049	-0.142	-0.130	-0.076	0.016	-0.123	0.103	0.036	-0.027						
HHM	0.137	0.012	-0.077	0.012	0012	-0.099	-0.136	-0.103	0.072	-0.024	0.045	0.020	0.029	0.120					
GOR	-0.078	0.010	0.048	0.010	0010	-0.006	-0.023	-0.021	-0.116	0.062	.256**	.587**	0.097	0.019	0.065				
UOW	0.003	0.029	0.060	0.029	0.029	-0.093	-0.080	-0.020	-0.078	-0.052	.305**	.178*	.183*	-0.059	0.075	.230**			
RFT	-0.051	0.015	0.086	0.015	0.015	0.093	0.115	-0.032	0.010	.238**	0.137	0.000	.187*	-.220**	0.064	0.076	0.144		
TAT	-0.046	0.058	-0.033	0.058	0.058	-0.036	0.011	-0.101	-0.029	0.002	-0.014	-0.085	.597**	-.161*	0.052	0.062	0.107	.164*	

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

Fig. 2. Correlation matrix (Pearson).

5.2.2. Linear regression

The correlation matrix indicated a direct correlation among age group (PAG), experience in software development (ESD), and experience in agile/scrum (EAS), leading to the inclusion of ESD as the representative variable for age/experience in regression models. Five regression models were established for each dependent variable, with each model incorporating variables from the previous one. The sequence of model construction was as follows:

1. Control variables: participant demographics (gender, education, age/experience).
2. Control variables: company characteristics (average project duration, company size).
3. Control variables: project context (participant's role in the team, average team size).
4. Independent variables: variables with low correlation in the correlation matrix (low correlation coefficient and nonsignificant).
5. Independent variables: variables with high correlation in the correlation matrix (high correlation coefficient and significant).

For the structural model estimation, both R^2 measures and path coefficients level of significance were used. As seen in Fig. 3, this study's dependent variables "Goal Orientation" scored an R^2 of 43.6% in Table 5; "Understanding of Work" scored an R^2 of 13.4% in Table 6; "Respect for Teammates" scored an R^2 of 12.3% in Table 7; and "Team Atmosphere" scored an R^2 of 35.2% in in Table 8.

The Adjusted R^2 of "Goal orientation" is .436 in Table 5, explaining 43.6% of the variance. A variance inflation factor (VIF) statistics indicated no multicollinearity concerns. Residual plots demonstrated normal error distribution, with no signs of heteroscedasticity. AGR and CON had standardised β values of .312 and .624 respectively in Table 9. Therefore, $H3_1$ and $H2_1$ are partially accepted, as GOR is a component of Shared Mental Models.

The Adjusted R^2 of "Understanding of Work" is .134 in Table 6, indicating that this model explains 13.4% of the variance, signifying weak relationships. VIF statistics confirmed the absence of multicollinearity, and residual plots demonstrated normal error distribution with no signs of heteroscedasticity. The standardised β values for AGR, EXT, and CON are .318, .209, and .183, respectively in Table 9. Therefore, $H1_1$ is partially accepted, while $H2_1$ and $H3_1$ are accepted (based on the findings from "Goal Orientation" and "Understanding of Work"). However, $H5_1$, $H4_1$, and $H6_1$ are rejected since "Goal Orientation" and "Understanding of Work" did not establish significant relationships between EMO, OEX, and HHM with Shared Mental Models.

"Respect for Teammates" achieved an Adjusted R^2 of .123 in Table 7, indicating a very weak relationship, bordering on unacceptability.

Table 5
Regression models summary, model 1 to 5.

Model summary Dependent variable: GOR					
Model	Vars. entered	R^2	Adj. R^2	R^2 Chng.	Sig.F Chng.
1	PGI, EDU, ESD	.009	−.008	.009	.658
2	APL, CSZ	.010	−.018	.001	.921
3	CTR, TSZ	.022	−.018	.012	.348
4	EMO, EXT, OEX	.047	−.017	.018	.371
5	AGR, CON	.477	.436	.430	.000

Table 6
Regression models summary, model 6 to 10.

Model summary Dependent variable: UOW					
Mdl.	Vars. entered	R^2	Adj. R^2	R^2 Chng.	Sig.F Chng.
6	PGI, EDU, ESD	0.004	−0.013	0.004	0.861
7	APL, CSZ	0.013	−0.015	0.009	0.441
8	CTR, TSZ	0.018	−0.022	0.005	0.672
9	EMO, OEX, HHM	0.034	−0.023	0.016	0.434
10	AGR, EXT, CON	0.196	0.134	0.163	0.000

VIF statistics confirmed the absence of multicollinearity, and residual plots demonstrated normally distributed errors with no signs of heteroscedasticity. EXT, EMO, and OEX had standardised β values of .184, −.198, and .228, respectively in Table 9. Therefore, $H1_2$, $H5_2$, and $H4_2$ are partially accepted.

"Team Atmosphere" achieved an Adjusted R^2 of .352 in Table 8, explaining 35.2% of the variance. The VIF statistics revealed no multicollinearity concerns. Residual plots indicated normally distributed errors with no signs of heteroscedasticity. EMO and EXT had standardised β values of −.139 and .596, respectively in Table 9. Combining the results of models "Respect for Teammates" and "Team Atmosphere", it is concluded that $H5_2$ and $H1_2$ are accepted, while $H2_2$, $H4_2$, and $H6_2$ are rejected.

The hypothesis testing summary is presented in Table 10.

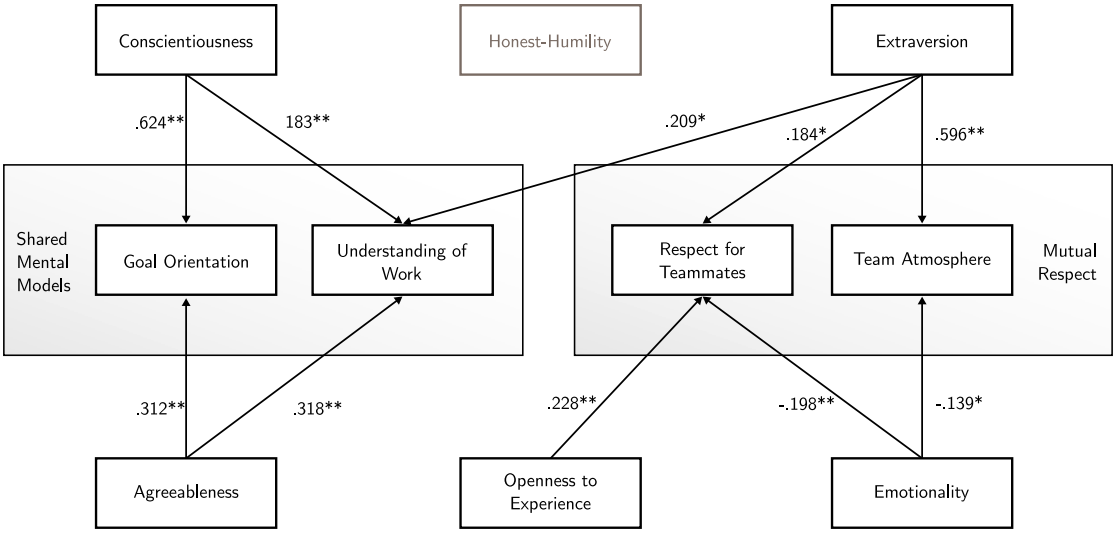

Fig. 3. Research Framework with results.

Table 7
Regression models summary, model 11 to 15.

Model summary Dependent variable: RFT					
Mdl.	Vars. entered	R^2	Adj. R^2	R^2 Chng.	Sig.F Chng.
11	PGI, EDU, ESD	0.011	−0.006	0.011	0.592
12	APL, CSZ	0.024	−0.004	0.013	0.308
13	CTR, TSZ	0.026	−0.014	0.002	0.861
14	AGR, CON, HHM	0.056	0.001	0.031	0.142
15	EXT, EMO, OEX	0.186	0.123	0.130	0.000

Table 8
Regression models summary, model 16 to 20.

Model summary Dependent variable: TAT					
Mdl.	Vars. entered	R^2	Adj. R^2	R^2 Chng.	Sig.F Chng.
16	PGI, EDU, ESD	0.007	−0.010	0.007	0.739
17	APL, CSZ	0.013	−0.015	0.006	0.566
18	CTR, TSZ	0.022	−0.018	0.009	0.471
19	AGR, CON, HHM, OEX	0.032	−0.031	0.010	0.793
20	EMO, EXT	0.399	0.352	0.367	0.000

Table 9
Regression coefficients.

Variable	Unstd. β	Std. β	t	Sig.	VIF
Dependent variable: Goal Orientation (GOR) (Model 5)					
Agreeableness (AGR)	0.222	0.312	5.432	0.000	1.050
Conscientiousness (CON)	0.446	0.624	10.851	0.000	1.054
Dependent variable: Understanding of Work (UOW) (Model 10)					
Agreeableness (AGR)	0.197	0.318	4.479	0.000	1.050
Extraversion (EXT)	0.130	0.209	2.937	0.004	1.054
Conscientiousness (CON)	0.118	0.183	2.577	0.011	1.048
Dependent variable: Respect for Teammates (RFT) (Model 15)					
Openness (OEX)	0.139	0.228	3.046	0.003	1.149
Extraversion (EXT)	0.110	0.184	2.581	0.011	1.048
Emotionality (EMO)	−0.118	−0.198	−2.739	0.007	1.071
Dependent variable: Team Atmosphere (TAT) (Model 20)					
Emotionality (EMO)	−0.097	−0.139	−2.242	0.026	1.071
Extraversion (EXT)	0.411	0.596	9.704	0.000	1.048

6. Discussion

The Scrum methodology centres around the team, yet there is limited literature on what factors contribute to the effectiveness of Scrum teams. While most research has focused on Agile as a whole, a formal definition of Scrum team effectiveness remains elusive. Salas' "Big Five" model of teamwork [32] has been a foundational concept, significantly influencing teamwork research in software development. This model has enhanced our understanding of how effective teams function by exploring cognitive and behavioural dynamics. The Agile Team Effectiveness Model (ATEM) [18] refines Salas' model for Agile teams, offering a specific framework for evaluating their effectiveness with five components and three coordinating mechanisms.

To address the research question in this study, individual characteristics, particularly personality traits according to the HEXACO model [27], were examined to understand how they influence the three coordinating mechanisms in the ATEM [18]. Data were collected from 181 software development professionals working with Scrum in five mature Vietnamese companies, and statistical analysis revealed several causal relationships. It is worth noting that the sample included respondents with varying levels of experience with Agile methodologies, but due to the convenience sampling method, there are limitations in generalising the research findings. The companies that were the focus of the research are mature organisations, leading to the inference that even if individual team members would not be experienced in Scrum, their teams as a whole would be, and thus relevant to the performance of mature Scrum teams.

Scrum advocates often argue for team sizes between 6 to 9 participants. It is clear that for many participants this is not the day-to-day reality. For larger projects that exceed the size of a single team, scrum is often adapted or integrated into larger frameworks [50] such as SAFe [51,52], LeSS [53] or Scrum@Scale [54] (which still rely on individual teams). We did not ask whether participants used these approaches instead of "pure" Scrum. We know that the businesses have various projects, where some projects use multiple teams with overall project staffing of up to 60 persons, but other projects use single teams. The individual projects therefore are varied in complexity, size and often work in single teams, representing the actual IT project market in Vietnam. However, as the organisations themselves were medium

Table 10
Hypothesis summary.

Hypothesis		Detail	Status
H1	$H1_1$	Extraversion is positively associated with Shared Mental Models	Partially accepted
	$H1_2$	Extraversion is positively associated with Mutual Respect	Accepted
	$H1_3$	Extraversion is positively associated with Communication	Untested
H2	$H2_1$	Conscientiousness is positively associated with Shared Mental Models	Accepted
	$H2_2$	Conscientiousness is positively associated with Mutual Respect	Rejected
	$H2_3$	Conscientiousness is positively associated with Communication	Untested
H3	$H3_1$	Agreeableness is positively associated with Shared Mental Models	Accepted
	$H3_2$	Agreeableness is positively associated with Mutual Respect	Rejected
	$H3_3$	Agreeableness is positively associated with Communication	Untested
H4	$H4_1$	Openness to Experience is positively associated with Shared Mental Models	Rejected
	$H4_2$	Openness to Experience is positively associated with Mutual Respect	Partially accepted
	$H4_3$	Openness to Experience is positively associated with Communication	Untested
H5	$H5_1$	Emotionality is positively associated with Shared Mental Models	Rejected
	$H5_2$	Emotionality is positively associated with Mutual Respect	Accepted
	$H5_3$	Emotionality is positively associated with Communication	Untested
H6	$H6_1$	Honest-Humility is positively associated with Shared Mental Models	Rejected
	$H6_2$	Honest-Humility is positively associated with Mutual Respect	Rejected
	$H6_3$	Honest-Humility is positively associated with Communication	Untested

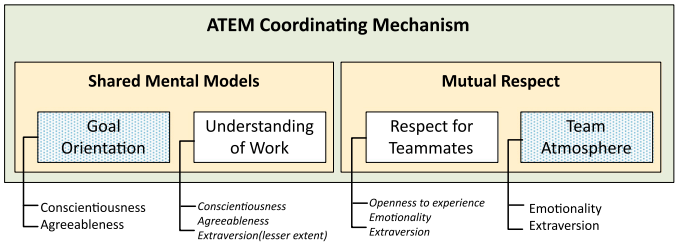

Fig. 4. ATEM coordinating mechanisms and their related components identified through factor analysis.

or large, there may be aspects of the scrum experience in smaller organisations (and the context of their teams) that are not reflected by the research. The impact of organisational context and maturity on Scrum team effectiveness (and needed personalities) would be an interesting avenue for future research.

Building on the ATEM, the study used the behavioural markers of the three coordinating mechanisms – Shared Mental Models, Mutual Respect, and Communication – as measurement scales. These behavioural markers were categorised into 10 separate groups under the three coordinating mechanisms during survey development. However, due to concerns about survey fatigue, not all behavioural markers were transformed into questions or variables, resulting in fewer factors for each component than desired. Factor analysis identified five components, and these components aligned with the expected coordinating mechanisms (see Fig. 4).

For Shared Mental Models, two components were extracted: Goal Orientation, related to project goals and vision, and Understanding of Work, related to tasks and processes. Mutual Trust yielded two components: Respect for Teammates, associated with respect and attitudes towards teammates, and Team Atmosphere, tied to social aspects of the team. In the case of Communication, only one component could be extracted, but it was not reliable and thus not included in regression modelling.

The components of the ATEM coordinating mechanisms (Goal Orientation, Understanding of Work, Respect for Teammates, and Team Atmosphere) were examined in regression models to test the proposed hypotheses. The regression models showed good fit for two relationships: Goal Orientation (Adjusted R^2 = 43.6%) and Team Atmosphere (Adjusted R^2 = 35.2%). However, model fit for Understanding of Work and Team Atmosphere was relatively modest, with Adjusted R^2 values of 13.4% and 12.3%, respectively. While the hypotheses related to these relationships were accepted or partially accepted, the lower fit could limit the generalisability of the results. Nonetheless, these findings suggest that Scrum team effectiveness can be assessed and predicted by measuring the personality traits of individual team members.

The study's findings have four implications. Firstly, the Shared Mental Models component was divided into two parts: Goal Orientation and Understanding of Work. Goal Orientation relates to the alignment with team goals, while Understanding of Work emerged as a residual factor from the analysis. Both components were analysed despite the latter's residual nature. For Goal Orientation, Conscientiousness and Agreeableness had significant effects (.624** and .312**, respectively), as highlighted in Figure 14, aligning with previous research [33,43,45,47]. Individuals high in these traits tend to be more effective in Agile teams due to their disciplined, organised approach and their focus on goal-oriented collaboration. These findings suggest that organisations and project managers can enhance team performance by tailoring team composition and goal-setting to align with these traits.

In contrast, the model fit for Understanding of Work was weaker, with an Adjusted R^2 of 13.4%. While Conscientiousness and Agreeableness remained predictive, Extraversion played a smaller role. The complexity of integrating diverse tasks, processes, and product outcomes likely influenced these results, limiting the model's practical applicability. Despite the model's low predictive power, Conscientiousness and Agreeableness remain important traits for successful Scrum teams [11,33,43].

Secondly, Mutual Respect was divided into two components: Respect for Teammates and Team Atmosphere. Similar to Shared Mental Models, these factors encountered challenges during factor analysis. The model for Respect for Teammates approached the threshold of unacceptability. Extraversion, Openness to Experience, and Emotionality were significant predictors, though further investigation is needed to fully understand the relationships between these traits and behavioural markers of Mutual Respect. Each personality trait may exert a stronger influence on different aspects of the scale. Like the Understanding of Work model, practical applications should be approached cautiously given the model's weakness. Prior research offers limited support for strong relationships between these traits and team effectiveness. While Extraversion positively influences team effectiveness, it is primarily in

customer-centric contexts, suggesting its influence may not extend to respect-related dynamics. Openness to Experience has been linked to innovation within teams [7], which could foster social friction. Given that the Respect for Teammates component includes conflict propensity, this effect may be confounded. Lastly, Emotionality (or Neuroticism) lacks theoretical support for influencing team effectiveness.

Contrary to our hypothesis ($H3_2$), Agreeableness was not positively associated with Mutual Respect in Scrum teams (see Table 10). This finding diverges from prior studies suggesting that Agreeableness, characterised by empathy and cooperation, enhances interpersonal dynamics in software teams [44]. Notably, Alami et al. [22] found that empathy fosters psychological safety in agile teams, a construct related to Mutual Respect, indicating that contextual factors may influence these relationships. In Vietnamese Scrum teams, which often include larger team sizes (12–14 members), cultural or structural factors may attenuate Agreeableness's effect.

The model for Team Atmosphere showed a stronger fit, with an Adjusted R^2 of 35.2%, as depicted in Figure 14. Extraversion and Emotionality were the key predictors, with Extraversion demonstrating the second-highest predictive power (.596**). Since Team Atmosphere relates to social dynamics, prior research indicates Agile teams tend to prefer extraverted individuals [45]. Active participation in Scrum processes further supports the role of Extraversion, as it facilitates smooth navigation through team interactions. Extraverted team members are also well-suited for customer-centric roles [46], making Extraversion a vital trait for Scrum team members in ensuring effective communication within and beyond the team. Scrum practitioners should consider Extraversion when forming teams and assigning responsibilities.

Third, the use of the 24-item HEXACO inventory validated its utility despite criticisms of short inventories [57]. Parallel analysis was used to extract six components, but some items, such as those for Honesty-Humility, had to be removed due to low loading coefficients. This suggests the inventory could either be shortened to 18 items or refined in wording to improve the validity of the 24-item version. Cronbach's alpha was high for all traits except Honesty-Humility, addressing concerns raised in previous research. The issues with Honesty-Humility may result from social desirability bias in self-reports or theoretical limitations of the trait itself. These findings suggest the HEXACO model could be further refined.

Lastly, the ATEM demonstrated its potential utility as a research tool. While not all behavioural markers from the original model were included, and some unexpected outcomes emerged during factor analysis, the overall results were satisfactory. The inability to fully extract components may have contributed to lower reliability statistics. Future research should include all behavioural markers, along with redundancy items, to better capture the significance of each marker and provide a more comprehensive understanding of team dynamics. Additionally, this study focused on only two of the three coordinating mechanisms, leaving one mechanism and five core components unexamined. Future studies on Agile Team Effectiveness, particularly in Scrum teams, should explore all eight components to validate the ATEM model further.

Furthermore, our findings on personality traits complement Alami et al. [22]'s work by quantifying the role of traits in fostering psychological safety, offering practical guidance for Scrum team composition in Vietnam.

6.1. Practical implications

After identifying the key personality traits influencing the success of Scrum software development projects, several practical recommendations emerge to guide managers in making more informed decisions. To enhance project outcomes, traits such as Extraversion, Agreeableness, Conscientiousness, Openness to Experience, and Emotional Stability should be aligned with the specific demands of each role. Incorporating these traits into organisational project management standards can help structure teams more effectively, thereby improving overall success rates.

Individuals high in Conscientiousness and Agreeableness are particularly suited to Scrum practices, as they contribute to team dynamics through discipline, organisation, tolerance, and goal-oriented collaboration. Managers can optimise team performance by tailoring team composition to match these personality traits. Additionally, Extraversion and Emotional Stability emerged as significant predictors of success, with Extraversion playing a critical role. Scrum teams benefit from extraverted individuals who excel in roles requiring frequent interaction, such as customer-focused practices. This highlights the importance of Extraversion in facilitating efficient communication both within the team and with external stakeholders.

Leveraging these findings, project managers can design goal-setting processes that resonate with the natural predispositions of team members; this alignment can lead to more cohesive decision-making and improved iterative processes within Scrum teams. Furthermore, forming teams based on personality composition and assigning roles accordingly is essential. Members with high scores in Conscientiousness and Agreeableness can be entrusted with roles that require planning or frequent collaboration. Given that the regression model for these relationships showed the highest fit, this effect is particularly noteworthy and deserves attention in team formation strategies.

To ensure optimal team capability, it is crucial to build teams composed of highly motivated professionals committed to project success. Providing adequate technical training focused on both subject matter and Scrum processes ensures team synchronisation. A team facilitator, ideally an expert in Scrum principles, should adopt a flexible, adaptive management style that promotes continuous learning and responsiveness to changes.

In summary, a successful Scrum environment is built on skilled and committed professionals. By recognising the impact of personality traits and providing appropriate training and leadership, managers can prioritise key factors that significantly enhance both project success and team effectiveness.

6.2. Limitations

This study has certain inherent limitations that need acknowledgement, spanning various aspects of research design and methodology. These limitations include sample concerns, measurement accuracy, study design, statistical analysis, and model assumptions:

Sample Concerns: The sample size was deemed sufficient for the target population, but the precise population quantity remains uncertain. Convenience sampling introduced potential selection bias. The study focused exclusively on Vietnamese software development professionals mostly recruited from five medium to large firms, overlooking regional variations within Vietnam, and smaller businesses. The sample inadvertently consisted of a homogenous subset of software professionals who had remained in their careers, limiting diversity. For three of the businesses, they would be running larger (up to 40 or 60 members) multi-team projects where scrum requires adjustment for inter-team coordination and management. The overall team sizes are such that day-to-day work would likely still be seen classed as Scrum by the participants, even if it is a variant that requires more personal skills that relate to inter-team coordination. Future research should adopt more rigorous sampling techniques and collect further demographic information.

Measurement Accuracy: Self-reporting in the questionnaire could introduce bias, particularly in questions susceptible to social desirability bias. Constructing a new questionnaire for dependent variables instead of adapting established measures may affect psychometric properties. More thorough testing techniques should be employed. An insufficient number of questions were developed for the ATEM's theorised latent variables, compromising validity and reliability. Future research should ensure adequate question development.

Design of Study: Misalignment between the study's theoretical basis and the application of behavioural markers for measurements was noted. The ATEM describes team-level behavioural markers, which ideally should be assessed collectively for each team, not individually for team members. Future research should focus on measuring ATEM's behavioural markers at the team level.

In contrast to Alami et al. [22], who found empathy enhances psychological safety in agile teams, our null finding for Agreeableness and Mutual Respect may reflect Vietnam's collectivist culture, where group norms overshadow individual traits. Larger team sizes (12–14 members) in our sample, compared to Scrum's ideal 5–9, may further attenuate interpersonal effects, as coordination challenges dominate [68]. Future research could test psychological safety as a mediator between Agreeableness and team effectiveness, extending the framework by Alami et al. [22] to Vietnamese contexts.

Statistical Analysis: EFA, while useful for established instruments, may require careful consideration for newly developed, untested measurements. Future studies should focus on measuring ATEM's proposed behavioural markers using Confirmatory Factor Analysis (CFA) and techniques like Partial Least Squares Structural Equation Modelling (PLS-SEM) for comprehensive validation.

Model Assumptions: Assumptions related to regression modelling include linearity, normality of errors, and homoscedasticity. Standardised residuals plots and scatter plots showed no significant deviations from these assumptions. Multicollinearity was not present, as indicated by the Variance Inflation Factor statistics.

Limitations on personality factors: Personality factors are inherently only a facet of team members, and other factors should not be disregarded. Beyond these factors, it is likely that teams would work well with diverse personalities that provide diverse strengths for diverse challenges.

Acknowledging these limitations is essential for interpreting the study's findings and guiding future research efforts.

7. Conclusions

This study aimed to address the research question: "What are the effects of personality traits on the effectiveness of Scrum teams?" This is a relatively unexplored area of research. The study proposed six main hypotheses with sub-hypotheses based on existing literature and employed a quantitative methodology, utilising statistical analysis techniques to establish relationships between variables. Personality traits were measured using the HEXACO model, and Scrum Team Effectiveness was assessed using the coordinating mechanisms of the Agile Team Effectiveness Model (ATEM). A survey was developed, and data were collected from 181 software development professionals in Vietnam.

The results of correlation analysis and linear regression modelling showed that personality had relatively small effects on Scrum Team Effectiveness (see Fig. 3). Notably, Agreeableness and Conscientiousness had the most significant positive effects on Shared Mental Models, while Extraversion positively affected Mutual Respect, and Emotionality had a negative impact on Mutual Respect. Some weaker relationships were identified, but they lacked practical significance. The Honest-Humility trait did not exhibit any predictive power. In summary, Scrum teams benefit from members with high scores in Extraversion, Agreeableness, Conscientiousness, Openness to Experience, and low scores in Emotionality.

The significance of this research lies in its exploration of personality effects on Scrum teams, its alignment with existing literature, the validation of the 24-item HEXACO questionnaire, and the use of ATEM as a measurement foundation. Additionally, the study provides managerial implications for Scrum practitioners and highlights its limitations, paving the way for future research.

Based on the limitations identified in Section 6.2, several future research directions can be pursued to address these shortcomings and enhance the robustness and generalisability of findings.

To improve sampling, future research should use more rigorous and representative techniques, such as stratified random sampling or cluster sampling, to capture a wider range of software development professionals across different regions and career stages in Vietnam. Expanding the study to include professionals from other countries could also provide insights into cultural and regional variations in team dynamics and behaviours. Future research should also explore the relationship between team size, Extraversion, and team effectiveness, as increasing team size can heighten relational complexity, which may impact overall team performance.

For better measurement accuracy, future studies should use well-established and validated questionnaires for assessing dependent variables instead of developing new instruments. This would enhance reliability and validity. Incorporating mixed methods, such as qualitative interviews or observational studies, could mitigate biases from self-report questionnaires. Ensuring a sufficient number of questions for latent variables would also improve measurement validity and reliability.

Aligning the study design more closely with the theoretical framework is crucial. Specifically, for studies using the ATEM framework, behavioural markers should be measured at the team level rather than individually, allowing for a more accurate capture of team dynamics and interactions.

Future research should employ advanced statistical techniques like Confirmatory Factor Analysis (CFA) and Partial Least Squares Structural Equation Modelling (PLS-SEM) to validate new instruments and theoretical constructs. These methods offer a more robust approach to testing hypotheses and assessing variable relationships, especially in complex models. While maintaining model assumptions in regression analyses is important, future research should explore alternative statistical methods, such as non-parametric methods or robust regression techniques, to validate findings under different conditions.

By addressing these limitations, future research can enhance the generalisability, reliability, and validity of findings, contributing to a deeper understanding of factors influencing team dynamics and effectiveness in software development contexts.

CRediT authorship contribution statement

Duc Minh Truong: Formal analysis, Data curation, Conceptualization. **Lai Xu:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Paul Ton de Vrieze:** Writing – review & editing, Writing – original draft, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A.11 relates to Section 1 of the survey, while Table A.12 corresponds to Section 2 of the survey.

Data availability

Data will be made available on request.

Table A.11
Survey items: Independent variables.

Constructs	Items
Openness to experiences	OEX1 - I can look at a painting for a long time.
	OEX2 - I think science is boring.
	OEX3 - I have a lot of imagination.
	OEX4 - I like people with strange ideas.
Conscientiousness	CON1 - I make sure that things are in the right spot.
	CON2 - I postpone complicated tasks as long as possible.
	CON3 - I work very precisely.
	CON4 - I often do things without really thinking.
Agreeableness	AGR1 - I remain unfriendly to someone who was mean to me.
	AGR2 - I often express criticism.
	AGR3 - I tend to quickly agree with others.
	AGR4 - Even when I'm treated badly, I remain calm.
Extraversion	EXT1 - Nobody likes talking with me.
	EXT2 - I easily approach strangers.
	EXT3 - I like to talk with others.
	EXT4 - I am seldom cheerful.
Emotionality	EMO1 - I am afraid of feeling pain.
	EMO2 - I worry less than others.
	EMO3 - I can easily overcome difficulties on my own.
	EMO4 - I have to cry during sad or romantic movies.
Honest-Humility	HHM1 - I find it difficult to lie.
	HHM2 - I would like to know how to make lots of money in a dishonest manner.
	HHM3 - I want to be famous.
	HHM4 - I am entitled to special treatment.

Table A.12
Survey items: Dependent variables.
Source: Adapted from HEXACO [27,57].

Mechanism	Constructs	Behavioural markers	Items
Shared mental model	Common Understanding of Goals	Agreement on goals clear vision	CUG1 - I agree with my team's goal for the project.
			CUG2 - I think my team have a clear vision for the project.
	Common Understanding of Tasks	Clearly defined tasks unnecessary work	CUT1 - My tasks for the project are clearly defined.
			CUT2 - I have unnecessary work because the project's needs are misunderstood.
	Common Understanding of the Process	Good process work agreement	CUW1 - I think my team have a good work process.
			CUW2 - I follow my team's work process
	Common Understanding of the Product	Understanding of what is to be delivered clear specifications	CUP1 - I understand what is to be delivered for the project
			CUP2 - I think the specifications for the product is not clear enough.
Mutual trust	Respect	Respect for competence politeness	RSP1 - I think my teammates are good at their job.
			RSP2 - I try to be polite/courteous when working with my team.
	Social climate	Social activities Empowerment	SCL1 - I enjoy hanging out with my teammates after work.
			SCL2 - I feel like my teammates empowers me.
	Conflict	Conflict need for control	CFL1 - I regularly get into conflict with my teammates.
			CFL2 - I want to have more control within my team.
	Openness	Acceptance of diverging views blame	OPN1 - I like to hear different views from my teammates.
			OPN2 - I think my teammates makes a lot of mistakes.
Communication	Co-location	Physical presence Co-location	COL1 - I try to have a physical presence when working and communicating with my team.
			COL2 - I like to work near my teammates.
	Friendly Atmosphere	Fun Good atmosphere	FRA1 - I think it is fun to work with my team.
			FRA2 - I enjoy interacting with my teammates.

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