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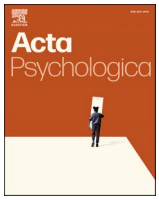

# Personality differences in flow experience during collaborative problem solving in work teams

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ABSTRACT

This study investigates the relationship between team members' personality traits and their perceived individual and team flow in collaborative problem-solving (CPS) contexts. Flow, a state of optimal experience, enhances motivation, performance, and satisfaction, benefiting both individuals and teams. Using multilevel regression analysis, we examined data from 60 participants across 15 work teams performing two CPS tasks, assessing individual and team flow separately. Linear regression revealed no noteworthy links between personality domains and individual flow. However, curvilinear analyses revealed various insights, with U-shaped relationships observed for Extraversion, indicating that individuals with either low or high levels of Extraversion tend to experience higher individual flow than those with moderate levels of this trait. Altruism/Agreeableness, while unrelated to individual flow, showed significant linear relationships with various team flow dimensions, including open communication and sense of unity. For team flow as well, curvilinear analyses revealed similar U-shaped relationships, mainly observed for Extraversion. The findings illustrate the nuanced role of personality in CPS and highlight the value of exploring curvilinear relationships besides linear relationships. Future research should examine the mechanisms underlying these relationships and their generalizability across contexts.

## 1. Introduction

Collaborative problem solving (CPS) is a dynamic process where individuals collaborate to solve problems by sharing understanding and effort (Fiore et al., 2018; Graesser et al., 2018). CPS requires ongoing evaluation of solution quality, task allocation, and labour division based on individual strengths, and interdependency among team members (Graesser et al., 2018; Herro et al., 2021). CPS is not without challenges. For instance, researchers (e.g., Chen, Inoue, et al., 2020) highlight issues such as social loafing, characterized by disengagement, which negatively impacts CPS processes and ultimately the quality of CPS outcomes (Graesser et al., 2018). These challenges underscore the importance of exploring factors that influence team dynamics, individual engagement, and the overall collaborative experience. Recent calls from various stakeholders (e.g., OECD, 2017; UNESCO, 2015) have emphasized the need to advance CPS science, shifting focus from cognitive and behavioural processes to motivational and affective dimensions (Molinari & Avry, 2018; Zhan et al., 2022), such as team emergent states. Incorporating flow theory into CPS research can foster our understanding of and enhance team dynamics and performance in both educational and work contexts (e.g., Molinari & Avry, 2018). Additionally, researchers have raised the need for further research on the role of personal characteristics in CPS (Buseyne, Rajagopal et al., 2024; Buseyne, Vrijdags et al., 2024; Graesser et al., 2018). In the following sections, we elaborate on flow theory, its application within CPS, and the role of personal characteristics.

### 1.1. Flow

#### 1.1.1. Individual flow

Flow is considered an important concept in positive psychology (Csikszentmihalyi, 2014). It denotes a state where a person is fully immersed in an activity, experiencing complete absorption without self-awareness but maintaining a profound sense of control (Abuhamdeh, 2020; Engeser et al., 2021; Nakamura et al., 2019; Nakamura & Csikszentmihalyi, 2014). It is considered the theory of optimal experience due

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to the positive interaction of motivation, affect, and cognition that characterizes it (Nakamura et al., 2019). This optimal experience enhances performance, and satisfaction in various settings, including education and the workplace (Engeser et al., 2021; Peifer et al., 2022). Flow, as originally conceptualized by Csikszentmihalyi (e.g., Abuhamdeh, 2020; Csikszentmihalyi, 2014; Nakamura & Csikszentmihalyi, 2014), encompasses multiple dimensions that can be categorized into two distinct groups: the characteristics of the flow experience itself and the conditions or antecedents that facilitate it. The defining characteristics of flow include intense and focused concentration on the task at hand, a seamless merging of action and awareness, a loss of self-consciousness, a sense of control over one's actions, a distortion of time perception, and the intrinsic enjoyment or reward derived from the experience. The conditions that enable flow consist of achieving a balance between the challenge presented by the task and one's skills, having clear and proximal goals, and receiving immediate feedback on one's progress (Abuhamdeh, 2020).

While the aforementioned conceptualization is widely embraced, researchers (e.g., Procci et al., 2012) have highlighted some limitations. For instance, Heutte et al. (2016) contend that not all flow dimensions are consistently experienced within educational contexts, posing challenges for its accurate assessment in these settings. In response, Heutte et al. (2021) refined the conceptualization by identifying a subset of dimensions that preserved the core essence of flow while simplifying its measurement. Their findings indicated that learners predominantly experience four dimensions: cognitive control, time transformation, loss of self-consciousness, and autotelic experience.

#### 1.1.2. Team flow

In recent years, flow theory has found broad application across various domains, including education (Gaggioli et al., 2011), sports (Mouelhi-Guizani et al., 2023), workplaces (Bakker, 2008), and the arts (Habe et al., 2019), contexts which are often inherently social rather than solitary. Consequently, the concept of flow has been extended to encompass experiences within social settings (Pels et al., 2018). This expansion acknowledges the potential for multiple individuals to simultaneously experience a synchronized and harmonious state of collective flow (Sawyer, 2015).

Indeed, recent research indicates that flow can also manifest at the team level, where the benefits of individual flow may be amplified, enhancing optimal team experiences, overall well-being, and meaningful interactions (Sawyer, 2015; van den Hout et al., 2018). This phenomenon is also termed social flow, group flow, or team flow. In collaborative contexts, and especially in CPS contexts, such concepts are particularly significant. The current article does not aim to provide an in-depth discussion of the various conceptualizations of the social dimensions of flow found in the literature. Instead, for a comprehensive overview, we refer readers to Pels et al. (2018) and Pels and Kleinert (2022). The current study adopts and expands upon the concept of team flow, as this is the most frequently applied framework within the context of work teams. Team flow is defined by van den Hout et al. (2018, 2019) as a shared experience resulting from an optimized team dynamic during interdependent tasks. It involves several prerequisites (i.e., collective ambition, common goal, aligned personal goals, high skills integration, open communication, safety, and mutual commitment) and characteristics (i.e., sense of unity, sense of joint progress, mutual trust, and holistic focus) that contribute to dynamic and synergistic team performance (van den Hout et al., 2018), fostering a cohesive and productive environment (e.g., Peifer et al., 2021). See Fig. 1 for a visual representation of the conceptual model of team flow.

### 1.2. Personality and flow

#### 1.2.1. Personality and individual flow

Personal characteristics, particularly personality traits, play a crucial role in flow experiences (Baumann, 2012), as it is widely acknowledged that some individuals have a greater propensity for experiencing flow (Tse et al., 2020). Previous studies on this so-called autotelic personality, which denotes the capacity to access flow readily (Tse et al., 2020), have mainly adopted the Big Five framework of personality. This framework includes five traits: Conscientiousness, Extraversion, Agreeableness, Openness, and Neuroticism—or Emotional Stability, its opposite (Hisler et al., 2020). Specifically, studies have shown positive relationships between flow on the one hand and Conscientiousness, Extraversion, and Openness on the other hand, while flow and Neuroticism generally showed a negative relationship (e.g., Annalakshmi et al., 2020; Marty-Dugas & Smilek, 2019; Olčar, 2019; Ross & Keiser, 2014; Sobhanmanesh, 2022; Tian & Ou, 2023). These relationships can partially be explained by how specific traits align with the conditions necessary for flow experiences. Conscientiousness, characterized by organization, self-discipline, and goal orientation (e.g., Kern, 2020), fosters sustained focus and persistence in tasks, facilitating flow (Sobhanmanesh, 2022). Extraversion promotes engagement in stimulating and dynamic activities (Annalakshmi et al., 2020) through its association with enthusiasm, sociability, and novelty-seeking (e.g., Walker, 2020). Furthermore, Extraversion is associated with higher levels of positive affect, lower levels of anxiety and depression, and extraverts not only participate in a greater number of social interactions but also derive more benefits from these interactions (Walker, 2020). Openness, linked to curiosity and creativity (e.g., Sparkman, 2020), encourages exploration of novel and challenging tasks conducive to flow (Sobhanmanesh, 2022). Conversely, Neuroticism, marked by emotional instability and susceptibility to negative affect (e.g., Zhang, 2020), inhibits flow by reducing an individual's capacity to focus and fully engage with tasks (Marty-Dugas & Smilek, 2019).

Various limitations can be observed in the current research examining the links between personality and flow. For instance, most studies on the relationship between personality and flow have conceptualized

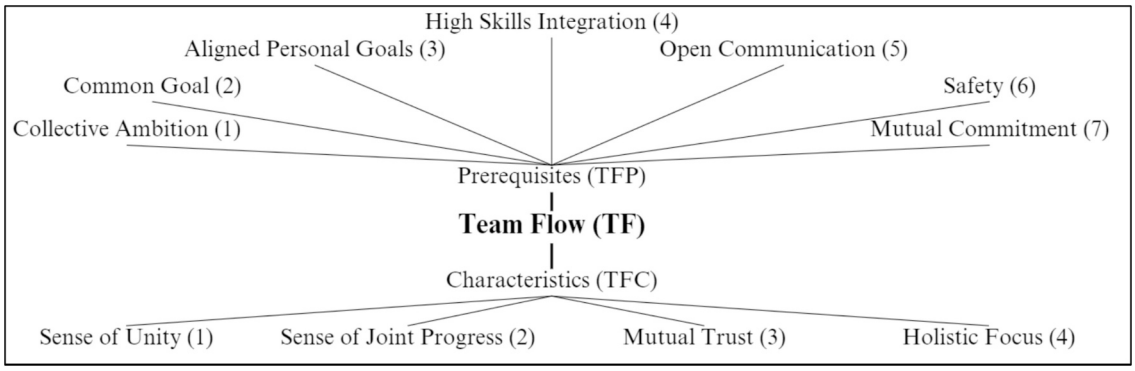


**Fig. 1.** Conceptual model of team flow.
Note. This figure is based on van den Hout et al. (2018).

flow as flow proneness rather than measuring it directly during or immediately after specific activities. Liu and Csikszentmihalyi (2020) also noted this limitation, recommending that future research measure flow in relation to real-world activities to obtain more accurate and reliable data. Additionally, while previous research has shown that the relationship between personality and flow may depend on context (Kranjčev & Vukasović Hlupić, 2021; Liu & Csikszentmihalyi, 2020), there is no previous research on personality and flow within CPS contexts. Flow in work teams is a relatively unexplored concept that significantly influences organizations, warranting a dedicated research focus (e.g., de Moura & Porto Bellini, 2020). The importance of studying the personality-flow relationship across contexts and considering such contextual differences is supported by at least two theories: the Trait Activation Theory and the Person-Environment Fit Theory. The Trait Activation Theory (Tett & Guterman, 2000; Tett et al., 2021) posits that personality traits are expressed in response to specific situational cues. This suggests that personal experiences depend on whether environmental triggers activate traits relevant to the task at hand. For instance, Extraversion might be activated in socially dynamic environments but may not be fully expressed in tasks requiring intense focus. The Person-Environment Fit Theory (e.g., de Cooman & Vleugels, 2022) emphasizes the alignment between individual traits and environmental characteristics. According to this theory, optimal experiences, such as flow, emerge when there is a good fit between personal attributes, such as personality, and situational demands. For instance, individuals high in Openness might thrive in creative and unstructured settings.

Moreover, while prior research has predominantly examined linear relationships between personality traits and flow (e.g., Schmidt et al., 2007), research suggests the potential for more nuanced dynamics. For instance, Osin et al. (2016) found that the relationship between the self-transcendence personality trait and flow could exhibit a curvilinear pattern. Additionally, previous research has demonstrated curvilinear associations between personality traits and other constructs, such as job performance (Le et al., 2011) and subjective well-being (Chen, Wang, et al., 2020). These studies underscore the possibility that traits within the Big Five framework might similarly reveal curvilinear relationships with flow, warranting further investigation.

#### 1.2.2. Personality and team flow

In addition to broadening our knowledge of the relationship between personality and individual flow, there is a need to explore the relationship between personality and team flow. This has been highlighted by Peifer et al. (2021), among others. While such research is currently lacking, the relationships between personality and related team emergent states have been explored in previous research. For instance, sense of unity, one of the team flow dimensions in the framework of van den Hout et al. (2018), is closely related to team cohesion, which includes task cohesion and social cohesion (van Vianen & De Dreu, 2001). Social cohesion involves the motivation to form social bonds, while task cohesion pertains to commitment to team goals. Aeron and Pathak (2012) found that Agreeableness positively relates to task cohesion, Extraversion to social cohesion, and Neuroticism negatively to both. Van Vianen and De Dreu (2001) identified similar relationships for Agreeableness and also identified positive relationships for Conscientiousness and Emotional Stability. Mutual trust, another team flow dimension, can also be related to personality (Sarker et al., 2003). Specifically, Barrick et al. (1998) suggested a positive relationship with Agreeableness, aligning with Costa and McCrae (2008), who described people scoring high on Agreeableness as trusting.

### 1.3. Research questions and hypotheses

Addressing the above-mentioned research gaps, the current study investigates how personality traits relate to perceived individual and team flow in CPS. Understanding how personality traits impact flow in CPS contexts can help in improving individual and team outcomes, as well as fostering environments that enhance both individual and collective optimal experiences. Therefore, the first research question (RQ1) is: "How is personality related to perceived individual flow in CPS?" Consistent with previous research on this relationship in distinct contexts, we hypothesize that Emotional Stability (H1), Extraversion (H2), Openness (H3), and Conscientiousness (H4) will positively relate to perceived individual flow, while Agreeableness (H5) will not show a significant relationship. The second research question (RQ2) is: "How is personality related to individuals' perceived team flow in CPS?" Given the lack of previous research on this topic, this question is exploratory. In addition to examining these research questions through a linear lens, the study also explores potential curvilinear relationships between personality traits and perceived flow. Due to the limited prior research on curvilinear dynamics in this context, this investigation is inherently exploratory.

## 2. Method

Data collection for this study was conducted as part of the Supporting Teamwork in Ambient Learning Spaces (STEAMS) project in 2022, during a professional CPS training for teams from various organisations in Flanders, Belgium. The training took place in an educational lab designed for collaborative learning. As detailed in Buseyne et al. (2023), the training included five phases: (a) introduction, (b) selection test, (c) introduction to CPS components, (d) end-game, and (e) debrief.

### 2.1. Study participants

Participants ($N = 60$) from fifteen existing teams in diverse organisations in Flanders, Belgium were recruited through convenience sampling. Each team consisted of four participants. The sample included 35 men, 24 women, and one undisclosed gender. Participants varied in age and professional background, including fields such as HR, IT, engineering, and accountancy. Most were aged 25–44 ($n = 52$), with smaller groups aged 45–54 ($n = 7$), 55–64 ($n = 3$), and 18–24 ($n = 2$).

### 2.2. Data-collection procedure

Participants were informed about the data collection procedure through an information letter and signed an informed consent form. The procedure was approved by the Ethical Committee of KU Leuven (G-2022-5202). Some weeks prior to the training, participants were asked to fill out a personality assessment. The actual training took place in the summer of 2022. During the training, participants performed CPS tasks in the second and fourth parts (see Buseyne et al., 2023). In the first CPS task (i.e., selection test), groups solved various small problems within 30 min, addressing abilities like verbal, numerical, logical reasoning, spatial insight, detail orientation, memory, and gaming. In the second task (i.e., end-game), teams had 90 min to design a temporary settlement, on a newly discovered planet. This task required analysing information sources about stakeholder needs, resources, and constraints (e.g., terrain, budget, interdependencies). Successful problem-solving required careful study of all information, good task distribution, and effective communication among team members. At the conclusion of each CPS task, participants were asked to complete a questionnaire designed to evaluate both individual and team flow experiences. These measures are specified in the subsequent section.

### 2.3. Measures

#### 2.3.1. Personality

Personality was assessed using the Business Attitudes Questionnaire (BAQ; Vrijdags et al., 2014), certified by the British Psychological Society (2014). This instrument is workplace-contextualized, making it particularly relevant in team-based settings, as shown by Buseyne et al. (2024). The BAQ assesses four facets within each of the Big Five

domains. These domains are labelled Emotional Stability (i.e., the opposite of Neuroticism), Extraversion, Openness, Altruism/Agreeableness, and Conscientiousness. Where Altruism is typically considered a facet under the Agreeableness domain in the traditional Big Five model, the BAQ refers to Altruism as the domain (Wille et al., 2018). Table 1 shows the dimensions and underlying facets, with definitions in Appendix A, Table A1 (see supplementary data). Each of the BAQ facet scores is calculated by averaging responses from six Likert-scale items, and Big Five domain scores are averaged from the relevant facets. The BAQ's predictive validity for performance has been supported by empirical findings (Wille et al., 2018), and its convergent validity is shown by significant correlations with the Big Five traits measured by other inventories, such as the OPQ32 (SHL, 2006): .46 (Emotional Stability), .51 (Extraversion), .47 (Openness), .64 (Altruism/Agreeableness), and .55 (Conscientiousness).

#### 2.3.2. Individual flow

Individual flow was measured using a Dutch version of the EduFlow-2 questionnaire by Heutte et al. (2021), which includes four subscales with three seven-point Likert scale items each: (a) cognitive control, (b) immersion and time transformation, (c) loss of self-consciousness, and (d) autotelic experience (see Table A2 in the supplementary data). Cognitive control assesses the ability to effectively navigate challenges. Time transformation measures perceived changes in time experience. Loss of self-consciousness reflects reduced self-awareness and concern about performance. Autotelic experience denotes well-being derived from the task. The brief format of EduFlow-2 reduces respondent burden and efficiently differentiates the four flow dimensions, correlating strongly with key motivational determinants in learning contexts (Heutte et al., 2021).

#### 2.3.3. Team flow

The Team Flow Monitor (TFM; van den Hout et al., 2019) was used to assess team flow. This questionnaire uses a seven-point Likert scale. The TFM consists of both team flow prerequisites (i.e., collective ambition, common goal, aligned personal goals, high skill integration, open communication, safety, and mutual commitment) and characteristics (i.e., sense of unity, sense of joint progress, mutual trust, and holistic focus). An overview of the items per team flow dimension is shown in Table A3 (see supplementary data). As shown in van den Hout et al. (2019), the validity of the TFM was established through exploratory and confirmatory factor analyses, revealing a second-order two-factor model of team flow with seven prerequisites and four characteristics. The instrument's reliability was confirmed through a test of internal consistency. The convergence of team members' perceptions provided evidence for both individual and collective flow experiences within the team dynamic. Furthermore, the TFM was found to be significantly related to individual and team-level outcomes, underscoring its utility in assessing and understanding team flow in the workplace (see van den Hout et al., 2019).

### 2.4. Data analysis

Data analysis was conducted using R (version 4.1.1). Descriptive analyses were performed to generate a summary of the target variables. To evaluate the relationship between personality traits and individuals' perceived individual and team flow, multilevel linear regression analyses were performed using the nlme package (Pinheiro et al., 2023) with maximum likelihood estimation. Each flow dimension was regressed on Big Five personality domains (i.e., Emotional Stability, Extraversion, Openness, Altruism/Agreeableness, and Conscientiousness).

Models were tested in two stages: (a) including only the linear effects of the personality domains, and (b) including both the linear and quadratic effects. The personality predictors were mean-centered, and for the quadratic terms, the mean of the squared values was subtracted from the squared variables.

The analyses accounted for the repeated nature of the measures by incorporating the individual as a Level 2 variable. Groups were not treated as an additional level due to the limited number of groups, considering guidelines by Leyland and Groenewegen (2020). However, group and task variables were included in all models as covariates. Model selection involved stepwise backward elimination through a likelihood-ratio test using the buildmer package (version 2.11; Voeten, 2023). Stepwise backward elimination is a systematic statistical method for optimizing regression models, beginning with a complete model containing all potential predictors and gradually eliminating those that do not significantly contribute to the model's explanatory power (Miller et al., 2022). Marginal and conditional R-squared ($R^2$) values for generalized mixed-effects models were computed using the MuMIn package (version 1.48.4; Bartoń, 2024). Marginal $R^2$ represents the proportion of variance explained by fixed effects, while conditional $R^2$ accounts for both fixed and random effects.

## 3. Results

Descriptive statistics for personality measures are presented in Appendix B and descriptive statistics for individual flow and team flow measures are presented in Appendices C and D (see supplementary data), respectively. Zero-order Pearson correlations between personality domains and flow measures for both tasks are presented in Appendix E (see supplementary data) to ensure transparency and reproducibility. All 60 participants from the 15 teams completed the personality questionnaire and the post-task questionnaire after the first CPS task. However, one participant did not complete the second post-task questionnaire, leaving 59 responses for the individual and team flow measures at that time.

### 3.1. Relationship between personality and perceived individual flow

Our first research aim was to explore the relationship between personality and individual flow. Table 2 presents the results of the multilevel regression analyses for the relationship between personality domains and individual flow experience, with task and team as covariates and the individual as Level 2. In models considering only linear relationships, no significant associations were observed between personality domains and overall individual flow. However, for the individual flow dimensions, a significant linear relationship was identified between Openness and cognitive control.

When quadratic effects were considered, several significant relationships emerged. Both the linear and quadratic effects of Extraversion were significant, not only for overall individual flow but also for specific dimensions, including cognitive control, loss of self-consciousness, and autotelic experience. These relationships exhibited

**Table 1**
Overview of the BAQ domains and facets.

| Emotional stability | Extraversion | Openness | Altruism/agreeableness | Conscientiousness |
|---|---|---|---|---|
| Relaxed | Leading | Abstract | People-oriented | Organised |
| Optimistic | Communicative | Innovative | Cooperating | Meticulous |
| Stress-resistant | Persuasive | Change-oriented | Helpful | Rational |
| Decisive | Motivating | Open-minded | Socially confident | Persevering |

**Table 2**
Results from the multilevel regression analyses for the relationship between the personality dimensions and perceived individual flow.

| | Individual flow | | Cognitive control | | Immersion and time transformation | | Loss of self-consciousness | | Autotelic experience | |
|---|---|---|---|---|---|---|---|---|---|---|
| (Intercept) | 5.75 (0.31)*** | 5.78 (0.29)*** | 6.00 (0.36)*** | 6.07 (0.37)*** | 5.48 (0.40)*** | 5.67 (0.37)*** | 5.60 (0.40)*** | 5.71 (0.37)*** | 5.78 (0.36)*** | 5.83 (0.35)*** |
| Emotional stability | | | | | | −8.17 (2.66)** | | | | |
| (Quadratic) | | | | | | 1.11 (0.38)** | | | | |
| Extraversion | | −3.20 (1.22)* | | −3.28 (1.51)* | | −3.13 (1.67) | 0.40 (0.21) | −4.54 (1.52)** | | −3.56 (1.45)* |
| (Quadratic) | | 0.49 (0.18)** | | 0.48 (0.22)* | | 0.46 (0.25) | | 0.73 (0.22)** | | 0.54 (0.21)* |
| Openness | | | 0.44 (0.20)* | | | 5.15 (2.27)* | | | | |
| (Quadratic) | | | | | | −0.71 (0.32)* | | | | |
| Altruism/A-greeableness | | | 0.15 (0.22) | | | | | | | |
| AIC | 285.33 | 280.20 | 351.81 | 352.12 | 333.26 | 328.73 | 351.11 | 341.66 | 331.09 | 327.78 |
| BIC | 335.21 | 335.62 | 407.22 | 407.54 | 383.13 | 395.22 | 403.75 | 397.07 | 380.96 | 383.20 |
| LL | −124.67 | −120.10 | −155.90 | −156.06 | −148.63 | −140.36 | −156.56 | −150.83 | −147.54 | −143.89 |
| $\sigma_{within}$ | 0.35 | 0.28 | 0.00 | 0.01 | 0.52 | 0.38 | 0.41 | 0.28 | 0.37 | 0.29 |
| $\sigma_{between}$ | 0.61 | 0.61 | 0.91 | 0.91 | 0.71 | 0.71 | 0.83 | 0.83 | 0.77 | 0.77 |
| $R^2$ marginal/ conditional | 0.41/0.56 | 0.46/0.56 | 0.45/0.45 | 0.45/0.45 | 0.24/0.51 | 0.36/0.51 | 0.40/0.52 | 0.46/0.52 | 0.39.51 | 0.43/0.51 |

Note. Regression coefficient estimates are shown, along with the corresponding standard error in parentheses and the *p*-value. *$p < .05$, **$p < .01$, ***$p < .001$. For each dimension, Model 1 represents the linear model without quadratic effects, while Model 2 includes quadratic effects. Predictors not selected for any model are excluded from the table. Considering recommendations of Hünermund and Louw (2023), the effects of covariates (i.e., group and task variables) are not shown.

a U-shaped trend (see Fig. 2), suggesting that both very low and very high levels of Extraversion are associated with higher flow experiences, while moderate levels correspond to lower flow.

Additionally, quadratic relationships were identified between Emotional Stability and Openness on one hand, and immersion and time transformation on the other. As illustrated in Fig. 3, the relationship between Emotional Stability and immersion and time transformation follows a U-shaped pattern. This indicates that both lower and higher levels of Emotional Stability are associated with greater immersion and time transformation. In contrast, the relationship for Openness exhibits an inverted U-shaped pattern, where moderate levels of Openness correspond to higher immersion and time transformation, while both

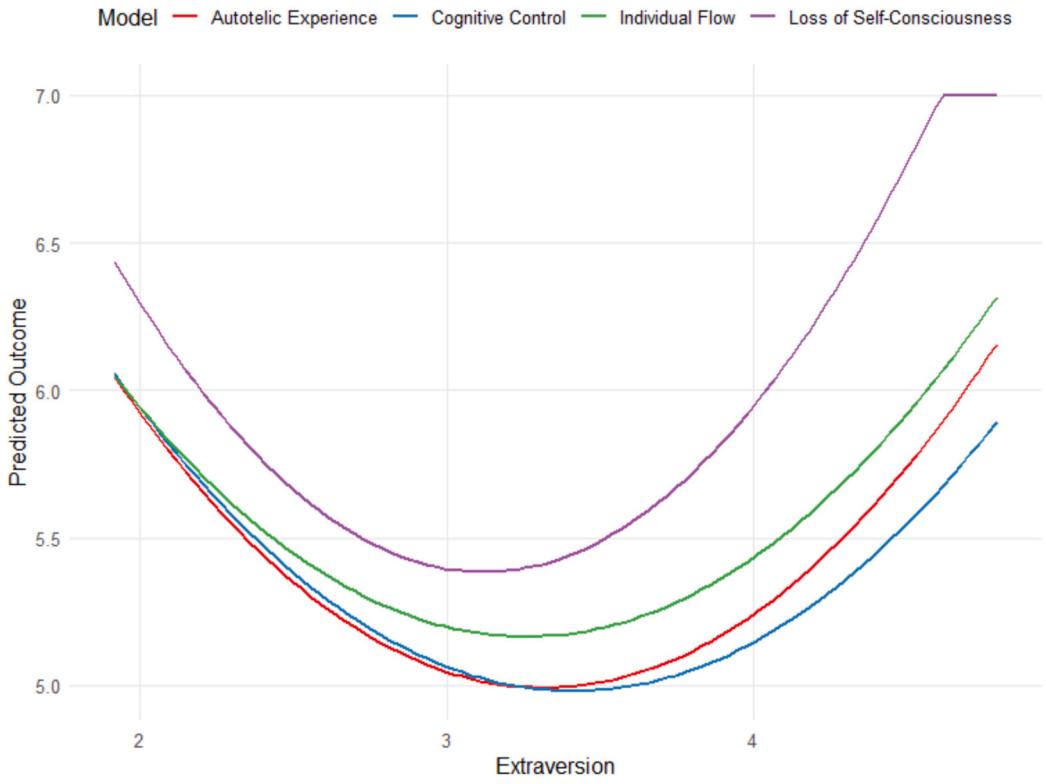


**Fig. 2.** Effect of extraversion on flow outcomes.
Note. Predictions were generated while controlling for the average effects of Group and, if applicable, other personality dimensions. Time was fixed to represent the baseline value.


**Fig. 3.** Effect of (A) emotional stability and (B) openness on immersion and time transformation.
Note. Predictions were generated while controlling for the average effects of Group and, if applicable, other personality dimensions. Time was fixed to represent the baseline value.

lower and higher levels of Openness are associated with reduced immersion and time transformation.

For most models, the marginal $R^2$ increased when quadratic terms were included, indicating that the fixed effects in these models accounted for more variance in the flow experience. For instance, for cognitive control, the marginal $R^2$ increased from .24 to .36.

### 3.2. Relationship between personality and perceived team flow

The second research question explored how personality relates to an individual's perceived team flow in CPS. Multilevel regression analyses examined the relationships between perceived team flow, including its prerequisites and characteristics, and personality domains (Table 3).

In the models considering only linear effects, a significant positive relationship was observed between Altruism/Agreeableness and team flow. Altruism/Agreeableness was also positively associated with the team flow prerequisites of collective ambition and aligned personal goals, although no significant relationship was found with the overall team flow prerequisites. Additionally, Altruism/Agreeableness demonstrated a positive linear relationship with overall team flow characteristics, with similar patterns emerging for the underlying characteristics of sense of unity and mutual trust. Beyond these findings, only one additional significant linear relationship was identified: between Conscientiousness and common goal. No other significant linear relationships were observed.

When quadratic terms were included, most of the previously described effects remained significant. However, the effect of Altruism/Agreeableness on overall team flow became non-significant, while an additional linear relationship emerged between Altruism/Agreeableness and the sense of joint progress. In addition, significant quadratic relationships were identified between Altruism/Agreeableness and the team flow characteristics of open communication and mutual trust, revealing a U-shaped trend (see Fig. 4). This pattern indicates that both low and high levels of Altruism/Agreeableness are associated with higher levels of open communication and mutual trust, whereas moderate levels of Altruism/Agreeableness correspond to lower levels of these team flow characteristics.

For Emotional Stability, significant quadratic relationships were found with two team flow prerequisites: common goal and mutual commitment. As shown in Fig. 5, similarly to the effects of Altruism/Agreeableness, the relationships exhibit a U-shaped trend, indicating that both low and high levels of Emotional Stability are associated with stronger perceptions of a common goal and mutual commitment.

Furthermore, Extraversion exhibited various significant effects. Specifically, it showed significant quadratic relationships with overall team flow, the overall team flow prerequisites, and the underlying prerequisites of collective ambition, high skills integration, and safety. Additionally, significant quadratic relationships were observed between Extraversion and the team flow characteristics, including the underlying characteristic of holistic focus. As illustrated in Fig. 6, these quadratic trends suggest that moderate levels of Extraversion are associated with the lowest levels of team flow outcomes, while both lower and higher levels of Extraversion correspond to increased team flow and its associated dimensions.

For most models, the inclusion of quadratic terms resulted in an increase in marginal $R^2$, reflecting improved variance explanation by the

**Table 3**
Results From the multilevel regression analyses for the relationship between the personality dimensions and perceived team flow.

| | Team flow | | Team flow prerequisites | | Collective ambition | | Common goal | | Aligned personal goals | High Skills integration | | Open communication | | Safety | | Mutual commitment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Intercept) | 6.20 (0.26)*** | 6.27 (0.25)*** | 5.97 (0.27)*** | 6.00 (0.25)*** | 6.36 (0.30)*** | 6.44 (0.30)*** | 6.14 (0.26)*** | 6.17 (0.26)*** | 4.65 (0.35)*** | 6.06 (0.36)*** | 6.13 (0.34)*** | 5.72 (0.43)*** | 5.58 (0.40)*** | 6.64 (0.33)*** | 6.71 (0.31)*** | 6.11 (0.33)*** | 6.16 (0.33)*** |
| Emotional Stability | | | | | | | | −3.56 (1.77) | | | | | | 0.37 (0.20) | | | −4.41 (2.25) |
| (Quadratic) | | | | | | | | 0.53 (0.25)* | | | | | | | | | 0.65 (0.32)* |
| Extraversion | | −2.89 (1.08)* | | −2.89 (1.08)* | | −2.62 (1.23)* | | | | | −3.91 (1.43)** | | | | −3.80 (1.30)** | | |
| (Quadratic) | | 0.42 (0.16)* | | 0.42 (0.16)* | | 0.36 (0.18)* | | | | | 0.55 (0.21)* | | | | 0.60 (0.19)** | | |
| Altruism/ Agreeableness | 0.36 (0.16)* | −1.99 (1.97) | 0.32 (0.16) | −1.99 (1.97) | 0.42 (0.18)* | 0.52 (0.21)* | | | 0.47 (0.21)* | | −1.25 (2.61) | | −7.67 (3.10)* | | | 0.38 (0.20) | |
| (Quadratic) | | 0.32 (0.27) | | 0.32 (0.27) | | | | | | | 0.24 (0.36) | | 1.09 (0.42)* | | | | |
| Conscientiousness | | | | | | | 0.46 (0.16)** | 0.43 (0.16)* | | | | | | | | | |
| AIC | 251.25 | 247.35 | 242.35 | 237.10 | 288.13 | 286.70 | 250.23 | 247.21 | 307.39 | 321.28 | 315.96 | 327.33 | 322.08 | 304.32 | 296.66 | 309.82 | 309.26 |
| BIC | 303.89 | 305.53 | 294.99 | 298.05 | 340.77 | 344.88 | 302.87 | 305.40 | 360.03 | 371.16 | 376.92 | 377.20 | 377.50 | 356.96 | 352.07 | 362.46 | 364.67 |
| LL | −106.62 | −102.67 | −102.17 | −96.55 | −125.06 | −122.35 | −106.11 | −102.61 | −134.69 | −142.64 | −135.98 | −145.66 | −141.04 | −133.16 | −128.33 | −135.91 | −134.63 |
| $\sigma_{within}$ | 0.29 | 0.24 | 0.36 | 0.29 | 0.31 | 0.27 | 0.30 | 0.25 | 0.44 | 0.44 | 0.32 | 0.66 | 0.58 | 0.38 | 0.29 | 0.36 | 0.34 |
| $\sigma_{between}$ | 0.53 | 0.53 | 0.48 | 0.48 | 0.63 | 0.63 | 0.52 | 0.52 | 0.64 | 0.70 | 0.70 | 0.62 | 0.62 | 0.66 | 0.66 | 0.69 | 0.69 |
| R2 marginal and conditional | 0.34/0.50 | 0.39/0.50 | 0.36/0.59 | 0.44/0.59 | 0.38/0.50 | 0.41/0.50 | 0.40/0.55 | 0.44/0.55 | 0.40/0.59 | 0.30/0.49 | 0.39/0.49 | 0.28/0.66 | 0.36/0.66 | 0.30/0.47 | 0.37/0.47 | 0.23/0.40 | 0.25/0.40 |

| | Team Flow Characteristics | | Sense of Unity | Sense of Joint Progress | | Mutual Trust | | Holistic Focus | |
|---|---|---|---|---|---|---|---|---|---|
| (Intercept) | 6.62 (0.28)*** | 6.71 (0.28)*** | 6.52 (0.32)*** | 6.68 (0.29)*** | 6.64 (0.28)*** | 6.68 (0.27)*** | 6.62 (0.27)*** | 6.66 (0.35)*** | 6.79 (0.34)*** |
| Emotional Stability | | −0.15 (0.18) | | | | | | | −0.31 (0.22) |
| (Quadratic) | | | | | | | | | |
| Extraversion | | −2.52 (1.19)* | | | | | | | −3.25 (1.48)* |
| (Quadratic) | | 0.36 (0.18)* | | | | | | | 0.46 (0.22)* |
| Altruism/Agreeableness | 0.43 (0.17)* | 0.51 (0.20)* | 0.54 (0.19)** | | 0.48 (0.17)** | 0.41 (0.17)* | −3.67 (2.02) | | 0.44 (0.24) |
| (Quadratic) | | | | | | | 0.56 (0.27) * | | |
| Conscientiousness | | | | | −3.21 (2.06) | | | | |
| (Quadratic) | | | | | 0.46 (0.28) | | | | |
| AIC | 287.08 | 287.59 | 323.67 | 299.52 | 291.95 | 268.91 | 266.23 | 340.06 | 338.52 |
| BIC | 339.73 | 348.54 | 376.31 | 349.39 | 350.13 | 321.56 | 321.64 | 389.93 | 399.48 |
| LL | −124.54 | −121.79 | −142.84 | −131.76 | −124.97 | −115.46 | −113.11 | −152.03 | −147.26 |
| σwithin | 0.12 | 0.00 | 0.12 | 0.00 | 0.00 | 0.26 | 0.22 | 0.21 | 0.00 |
| σbetween | 0.69 | 0.68 | 0.80 | 0.74 | 0.70 | 0.59 | 0.59 | 0.85 | 0.84 |
| R2 marginal and conditional | 0.29/0.31 | 0.33/0.33 | 0.26/0.28 | 0.28/0.28 | 0.36/0.36 | 0.30/0.41 | 0.33/0.41 | 0.24/0.28 | 0.30/0.30 |

Note. Regression coefficient estimates are shown, along with the corresponding standard error in parentheses and the p-value. *p < .05, **p < .01, ***p < .001. For each dimension, Model 1 represents the linear model without quadratic effects, while Model 2 includes quadratic effects. Predictors not selected for any model are excluded from the table. Considering recommendations of Hünermund and Louw (2023), the effects of covariates (i.e., group and task variables) are not shown.

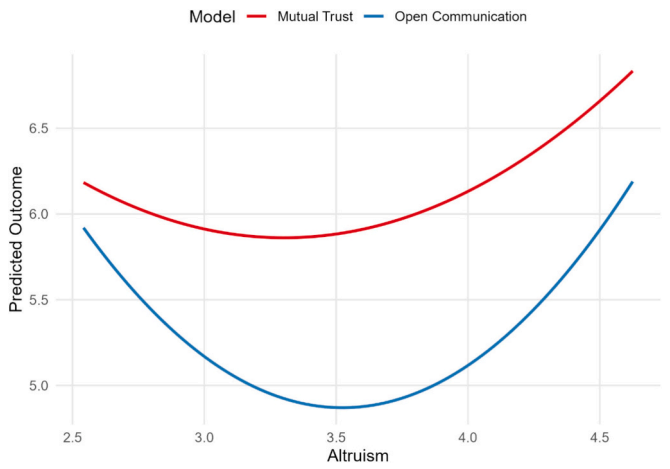


**Fig. 4.** Effect of altruism/agreeableness on mutual trust and open communication.
Note. Predictions were generated while controlling for the average effects of Group and, if applicable, other personality dimensions. Time was fixed to represent the baseline value.

fixed effects. For instance, marginal $R^2$ increased from .34 to .39 and from .36 to .44 in two models.

## 4. Discussion

### 4.1. Personality and individual flow

RQ1 aimed to unravel the relationship between personality domains and perceived individual flow in CPS. Contrary to the initial hypotheses, the study found limited relationships between personality dimensions and individual flow. Specifically, individual flow did not significantly relate to Emotional Stability (H1), Extraversion (H2), and Conscientiousness (H4). Particularly, the relationship between Extraversion and flow does not align with previous research by Liu and Csikszentmihalyi (2020) who, in the context of social activities, demonstrated that extraverts experience flow more intensely. This suggests that the specific nature of CPS tasks (e.g., intense focus on problem-solving and coordination among team members) might not facilitate the same flow dynamics observed in more general social activities. Consistent with H5, no significant relationship was found between Agreeableness and individual flow. Regarding H3, while Openness did not significantly relate to overall individual flow experience, individuals with higher Openness experienced a heightened sense of cognitive control. This heightened cognitive control could be attributed to their abstract thinking, creativity, and adaptability, which enhance their confidence and ability to manage complex tasks in CPS. This aligns with McCrae's (1987) research, which found a positive association between Openness and divergent thinking, as well as with previous studies on creative achievement (Jauk et al., 2014) and problem-solving (Scherer & Gustafsson, 2015), which identified positive associations between these abilities and Openness. The variance in our results compared to previous research suggests that the link between personality traits and the experience of flow depends on specific context characteristics. This is consistent with the Person-Environment Fit Theory (de Cooman & Vleugels, 2022), which emphasizes that individual experiences, such as flow, are influenced by the alignment between personal attributes and environmental characteristics.

The inclusion of curvilinear relationships allowed for a larger portion of variance in flow experiences to be explained, highlighting the added value of exploring non-linear dynamics. This underscores the importance of moving beyond linear assumptions to fully understand how personality relates to flow. By complementing the linear findings, these curvilinear trends provide a deeper and more nuanced perspective on the complex interplay between personality traits and individual flow. The main observation in the findings was the curvilinear relationship between Extraversion and overall individual flow, which highlights that both highly introverted and highly extroverted individuals may find ways to engage deeply in CPS tasks. This aligns with the Trait Activation Theory, which posits that situational cues activate different traits

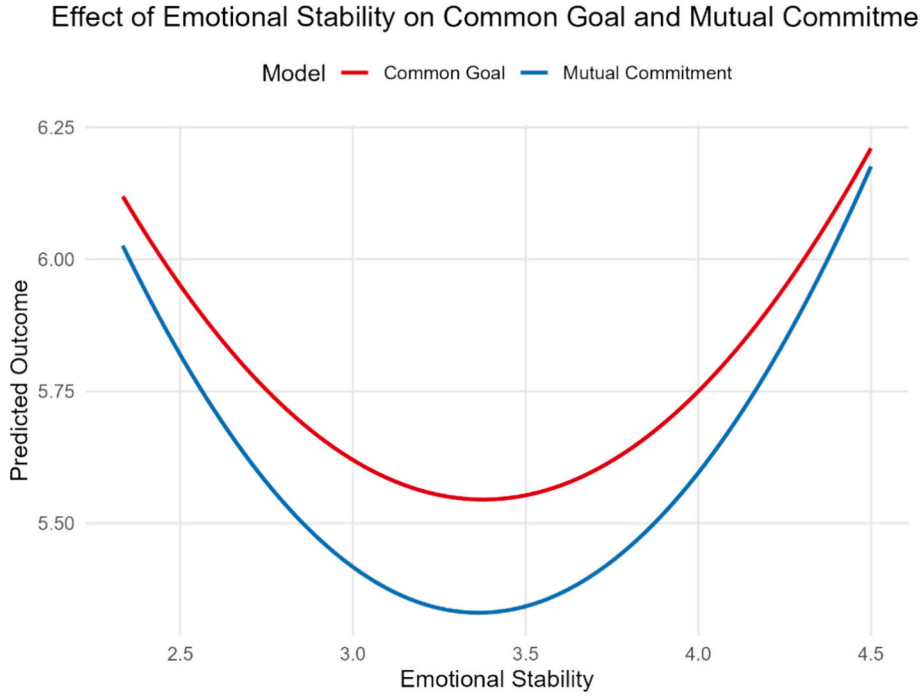


**Fig. 5.** Effects of emotional stability on common goal and mutual commitment.
Note. Predictions were generated while controlling for the average effects of Group and, if applicable, other personality dimensions. Time was fixed to represent the baseline value.

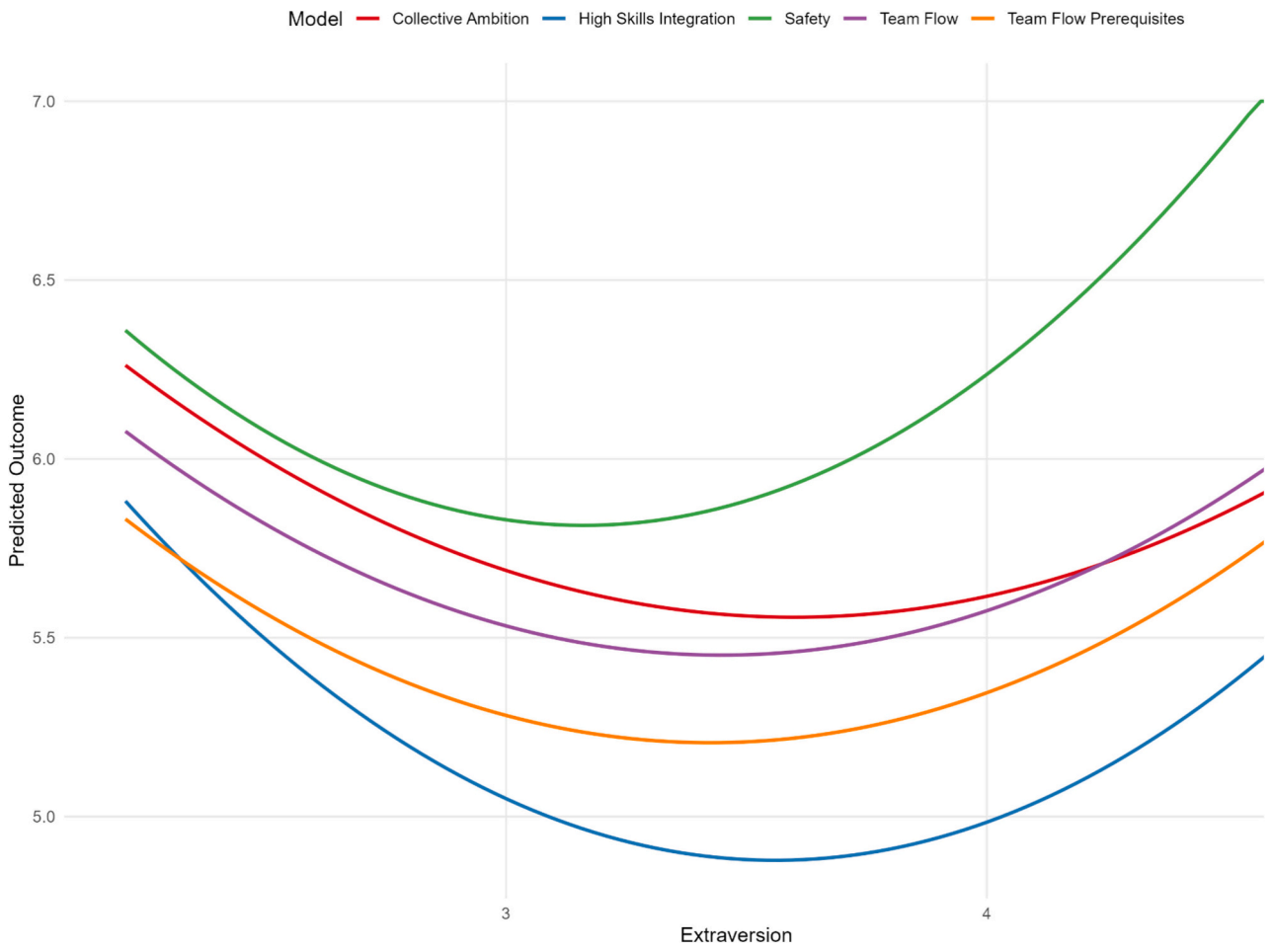


**Fig. 6.** Effects of extraversion on team flow outcomes.
Note. Predictions were generated while controlling for the average effects of Group and, if applicable, other personality dimensions. Time was fixed to represent the baseline value.

depending on the context. Introverts may thrive in CPS tasks due to their capacity for deep thinking and sustained focus (e.g., Blumenthal, 2001) while extroverts' quick decision-making and ability to navigate dynamic social interactions (e.g., Walker, 2020) may facilitate their engagement in these collaborative environments. Additional curvilinear relationships were observed between Emotional Stability and immersion and time transformation, as well as between Openness and this flow dimension. Both low and high levels of Emotional Stability were associated with greater immersion and time transformation. For Openness, moderate levels corresponded to higher immersion and time transformation, while lower and higher levels were associated with reduced immersion and time transformation. The mechanisms underlying these observed patterns require further exploration.

### 4.2. *Personality and team flow*

With *RQ2*, the study aimed to gain insights into the relationship between personality domains and team members' perceived team flow in CPS contexts. Emotional Stability, Extraversion and Openness were not significantly related to team flow. Individuals scoring higher on Altruism/Agreeableness showed a positive association with team flow and various team flow dimensions (i.e., Collective Ambition, Aligned Personal Goals, Characteristics of Team Flow, Sense of Unity, and Mutual Trust). The significant relationship with Sense of Unity is consistent with research on personality and team cohesion, such as the findings by Aeron and Pathak (2012) and Van Vianen and De Dreu (2001), which emphasize the importance of Agreeableness in promoting a cohesive team environment. Similarly, the positive relationship between Altruism/Agreeableness and Mutual Trust supports earlier work by Barrick et al. (1998), indicating that individuals who score high in Agreeableness tend to facilitate trust within teams. This suggests that a disposition towards Agreeableness can positively influence team dynamics. Furthermore, the study found that Conscientiousness was positively related to Common Goal, a shared understanding and commitment among team members to clear, agreed-upon objectives that provide a suitable challenge and guide their collaborative efforts (van den Hout et al., 2018). This finding aligns with Van Vianen and De Dreu (2001), who identified a positive relationship between Conscientiousness and task cohesion, highlighting that individuals with higher Conscientiousness contribute to a stronger alignment and commitment to team goals.

Curvilinear relationships captured additional variance in team flow outcomes, emphasizing the value of exploring non-linear dynamics. Specifically, Extraversion exhibited significant quadratic effects across multiple dimensions, including overall team flow, various team flow prerequisites (e.g., collective ambition, high skills integration, and safety), and the team flow characteristic of holistic focus. Individuals with both low and high levels of Extraversion experienced greater team flow outcomes, while those with moderate levels report lower team flow experiences. Additional findings showed that both low and high levels of Altruism/Agreeableness fostered stronger experiences of open communication and mutual trust and that both low and high levels of Emotional Stability contribute to stronger perceptions of common goal and mutual commitment. Although these findings underscore the significance of

considering curvilinear relationships, further exploration is needed to uncover and elucidate the underlying mechanisms driving these dynamics.

### 4.3. Limitations

It is important to highlight several potential limitations of this study. First, the relatively small sample size of 60 participants, distributed across fifteen teams and measurements at two time points, may limit the generalizability of the findings. Future research could benefit from a larger sample across additional contexts and time points to enhance robustness and external validity. Second, a larger number of teams would allow for multilevel analyses with participants nested within teams, whereas in the current study, team was added as a covariate in the regression models, aligning with recommendations of Leyland and Groenewegen (2020). Third, the nature of these analyses does not allow for causal inferences (Revelle, 2007) and the generalizability of the CPS tasks to other environments may also be limited due to context-specific factors, as described in the section on CPS tasks during the training. Fourth, it is important to note that the current study relied on self-reported measures for personality and individual and team flow only. Future research could explore alternative ways of measuring individual and team flow. Last, it is important to consider limitations of the Big Five framework used in this study. As discussed by Boyle (2008), critiques in previous research highlight its cultural and contextual dependency, methodological concerns in factor derivation, and the assumption that personality traits remain stable over time. Therefore, it is crucial to continue investigating these limitations to enhance the applicability of personality research across contexts.

### 4.4. Strengths

Despite these limitations, the study has several strengths. Including participants from diverse professional backgrounds enhances the study's applicability. Additionally, while various previous studies measured personality and flow simultaneously using a questionnaire, potentially leading to common method bias (e.g., Kock et al., 2021), this study mitigated such bias by temporally separating the personality and flow measures (Conway & Lance, 2010). Furthermore, the study's dual focus on individual and team flow in CPS is a significant strength, as research in this area is still in its infancy (e.g., Peifer et al., 2021). This study is the first to assess the relationship between personality and team flow experience in CPS contexts. The analyses are based on flow measures from two consecutive CPS tasks and were conducted directly in line with these tasks, following the recommendations of Liu and Csikszentmihalyi (2020). Last, in contrast with previous research assessing the link between personality and flow, the current study also considered the examination of curvilinear patterns.

### 4.5. Recommendations

Based on the current research and in line with previous literature, several recommendations for future research can be made. First, regarding the relationship between personality and team flow, our study highlights the need for a more comprehensive understanding of the factors influencing team flow. Therefore, future research should focus on building a nomological network for team flow to systematically map out the relationships with key variables, such as social cohesion and task cohesion. This approach could significantly enhance hypothesis development and provide a structured framework for advancing the research on team flow and the social dimensions of flow in general.

Second, since various studies in multiple contexts have assessed the relationship between individual flow and team flow, conducting a meta-analysis could help examine how different contextual variables influence the relationship between personality and flow. Such a study would provide valuable insights into the consistency and variability of these relationships across diverse settings.

Third, further exploration is needed to deepen our understanding of the generalizability of findings across diverse CPS contexts. Therefore, additional investigation into specific industry settings, considering variations in tasks and team structures, is recommended. This also aligns with recommendations of Peifer et al. (2021). The study could also be expanded by considering other assessments of flow, including a broader set of dimensions. For instance, future research in CPS contexts could benefit from using the Flow State Scale-2 (Jackson & Eklund, 2002) or experience sampling methods (Fullagar & Kelloway, 2009).

Fourth, building on Revelle (2007), future research could adopt experimental approaches to study the relationship between personality and flow, to allow for conclusions about causality. In addition to self-reported data, future studies might also use additional data sources, such as physiological data, to triangulate findings (Rissler et al., 2023). Although the explained variance in flow of such measures remains rather low, in combination with shorter questionnaires, it could allow researchers to study flow and team flow in a more dynamic and longitudinal way, as recommended by Ceja and Navarro (2012).

Fifth, future research might examine personality traits collectively within teams, including the average and variance in group personalities, to provide insights into how team composition influences individual and team flow in CPS contexts. For instance, exploring how complementary personality traits within a team reinforce high skill integration could further clarify the role of team composition in fostering optimal collaboration. Apart from focusing on individuals' perceived team flow, such research could also incorporate aggregated measures of team flow.

Finally, it would be valuable to reanalyse data from previous studies on the personality-flow relationship to explore the presence of curvilinear relationships.

### 4.6. Conclusion

This study highlights the nuanced relationship between personality and flow in CPS contexts, emphasizing the value of exploring curvilinear dynamics. The findings reveal the significance of Extraversion, Emotional Stability, and Openness for individual flow, as well as Altruism/Agreeableness and Conscientiousness for team flow, with notable curvilinear effects enhancing the understanding of these relationships. These results align with Person-Environment Fit and Trait Activation Theory, emphasizing the role of contextual factors in shaping flow experiences. The study's diverse participant pool and methodological strengths provide a solid foundation for future research. Future studies should focus on building a nomological network for team flow and exploring diverse CPS settings to deepen our understanding of these dynamics.

## CRediT authorship contribution statement

**Siem Buseyne:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis. **Thierry Danquigny:** Writing – review & editing, Conceptualization. **Fien Depaepe:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Jean Heutte:** Writing – review & editing, Conceptualization. **Annelies Raes:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

## Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT in order to enhance the readability of the text. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

## 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.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2025.105032.

## Data availability

Additional data and instruments, next to the ones included in the article and/or supplementary materials are not readily available because of their confidentiality. Further inquiries can be directed to the corresponding author.

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